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CHEMICAL SECTION.

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The Analytical Methods for Carbohydrates as Applied to Foods and Feeding Stuffs.

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(*Concluded from p. 366.*)

Large quantities of maple syrup are continually found on the market which consist of glucose mixed with a little genuine syrup and malted cane-sugar, the whole mass being flavored with an extract of hickory bark. The testimony given before the Committee on Manufactures of the United States Senate revealed to some extent the magnitude of this form of adulteration. The method of detection is in every respect similar to that described for table syrups. Maple syrups are sometimes adulterated by the addition of cane-sugar, and it is impossible to detect this adulteration, as the sugar of the cane and the maple are identical. In

cases of this kind the purchaser has to rely solely upon his experience with reference to the taste and flavor of the genuine product. The same may be said concerning maple-sugar which has suffered an addition of ordinary yellow sugar.

Honey is probably one of the most extensively adulterated foods, the usual adulterant being glucose. The deception is in many cases carried to such a point that the product offered as "genuine" consists totally of glucose, to which the manufacturer has added a piece of drained honeycomb to render the fraud more acceptable. A certain quantity of glucose is also frequently added, because it prevents the subsequent crystallization common in pure honeys and assures a product which is at all times clear and transparent.

Honey is as a rule levorotatory, the chief sugar present being invert-sugar, and a dextrorotatory product should be viewed at once with suspicion, as the dextrorotation may be due to the presence of an excessive amount of cane-sugar, glucose or both. It must be remembered, however, that honeys of known purity have been found which are dextrorotatory, noticeable instances being the pine-tree honeys, which are produced by bees feeding on the exudation formed on pines by a certain fungus. The dextrins contained in these honeys resemble those of commercial glucose very closely, so that a distinction is practically impossible. Fortunately, these products generally have a very unpleasant odor and an acrid taste and they are probably never used as a food, although their existence has frequently been taken advantage of by the defense in prosecutions for adulteration. According to Beckman the presence of glucose in honey may be detected qualitatively by the addition of methyl alcohol and a solution of barium hydroxid to the diluted honey. In the presence of glucose a weighable precipitate is obtained, while with a pure honey it is only slight. Methyl alcohol alone may be used for this test when pure honey yields only a slight flocculent precipitate which settles rapidly and is only faintly colored by an iodin-potassium iodid solution, while with glucose there is obtained a gummy deposit which attaches itself to the sides of the

beaker and gives with the iodin-reagent the reddish violet-reaction characteristic of the amylo-erythrodextrins. Naturally, both of these tests fail when a technically pure dextrose is used. The fermentation method may also be applied to honeys. Pure honey yields by this method a final solution which often possesses a slight dextrorotation, and authorities differ as to the allowable maximum. In any event it should not exceed + 3° when a 10 per cent. solution is polarized in a 200-millimeter tube. As a further proof, the final solution may be inverted with hydrochloric acid, when pure honeys will show only traces of reducing sugar; while honeys adulterated with glucose exhibit a correspondingly large amount of dextrose.

The addition of cane-sugar to honey is rather difficult to prove, as a normal honey may contain as much as 10 per cent. The presence of cane-sugar is frequently due to the fact that beekeepers use it as a food for the bees during the winter season. In Europe this is considered an adulteration. Comparatively small amounts of cane-sugar reduce the normal levorotation of the honey while larger amounts cause a dextrorotation. All such honeys exhibit after inversion an increased levorotation or a change from dextro- to levorotation. In the absence of glucose the quantity of sucrose is readily determined by the polarization or gravimetric determination of the invert-sugar before and after inversion. Pure honeys contain usually about 70 per cent. of invert-sugar, and the difference between invert-sugar before and after inversion never exceeds 8 per cent., while in honeys mixed with cane-sugar, this difference amounts to as much as 45 per cent. Molasses is rarely used in the adulteration of honeys and may be detected by the method given for cane-sugar. Beckmann has suggested a qualitative test depending on the addition of a solution of lead subacetate in methyl alcohol to the honey, sufficiently diluted, so that the lead subacetate alone does not produce a precipitate. In the presence of molasses a weighable precipitate is obtained, while pure honeys are at the most rendered only opalescent.

Rare cases are recorded where honeys have been adul-

terated by the addition of starch or flour. This is easily detected by treating the suspected sample with 70 per cent. alcohol and collecting the insoluble residue on a filter, when it may be examined microscopically or subjected to further analysis if a quantitative result is required. Instances are also known where the honeys have received an addition of invert-sugar. It is impossible to detect this form of substitution with certainty, owing to the fact that the adulterant is identical with the sugar normally present in honey.

Fruit Products.—Under this general heading are included fruit juices, jellies, jams and marmalades.

Fruit juices and syrups are subject to two forms of adulteration which can be proved by an estimation of the sugars. The former are frequently diluted with water whereby the composition of the syrups, of which they form the basis, is affected, and the latter receive, similarly to honey, etc., an addition of glucose. Unfortunately, the average composition of the various fruit juices is not sufficiently well known to establish appropriate standards. Huckleberry juice is extensively used in Germany and the composition has been studied by Spaeth,* who found that in a syrup prepared from a pure juice, the non-sugars, *i. e.*, the difference between the total solid matter and total sugar, never fell below 1·3 per cent., and he therefore concludes that all syrups whose non-sugars are found to be below this minimum have been prepared from a diluted juice.

The addition of glucose to fruit syrups is very generally practised, both on account of the low price of the adulterant and because its addition permits the use of a much smaller quantity of the most valuable constituent—the fruit juice itself. The latter is due to the fact that even so small an addition as 5 to 10 of glucose, to 100 of cane-sugar, prevents the subsequent crystallization and permits so-called cold mixing. In a pure syrup the same result is accomplished by using a large quantity of fruit juice and evaporating

* "Ztschr. für Untersuchung der Nahrungs- u. Genuss-mittel," **4**, 97; **4**, 921.

the mixture to the proper density, but this is naturally more expensive. The addition of glucose furthermore allows the use of less solid matter, because it imparts to the finished product a viscosity similar to that prepared from fruit juice and cane-sugar used in larger quantities.

The carbohydrates naturally present in a fruit syrup are cane-sugar and invert-sugar. The latter is in part introduced with the fruit juice and the remainder is due to the inversion of the cane-sugar subsequent to the manufacture. The presence of glucose can therefore be detected by the polarization before and after inversion and by the fermentation method. Spaeth has shown that pure huckleberry syrups show, after inversion of a 10 per cent. solution, a levorotation varying from 2° 20′ to 2° 44′. A dextrorotation after inversion or after fermentation is therefore positive proof of the addition of glucose. It must be noted, that in the preparation of the solution for polarization, a sufficient excess of lead subacetate must be added to insure the complete removal of malic acid and the malates, which influence the polarization, in that they are either levo- or dextrorotatory, depending on the concentration of the solution. Spaeth claims that an approximate estimate of the quantity of glucose present can be obtained by heating the fermented solution with hydrochloric acid and determining the resultant dextrose, it being assumed that the glucose contained from 30 to 40 per cent. dextrin. Owing to the wide variations in the composition of commercial glucose, this can be at the most only a very rough approximation, and for general purposes the mere proof of the adulteration is sufficient.

A determination of the cane-sugar present in a fruit syrup furnishes a valuable indication of the age of the product, as this sugar undergoes in time a slow inversion, owing to the presence of organic acids.

Jellies and Similar Products.—When pure, these foods are always prepared from the pulped fruit with the addition of a suitable quantity of cane-sugar. It is highly probable, however, that few of the products to-day on the market, especially the cheaper grades, are manufactured in this

manner. The most common form of adulteration is, as usual, the incorporation of varying quantities of glucose. Another form of sophistication which is very extensively practised in the preparation of the lower grades of jellies is the use, as a basis, of an apple-jelly made from the peelings and cores. This is mixed with glucose and then colored and flavored to resemble the fruit from which the finished product is claimed to be derived. A certain quantity of cane-sugar may also be added to increase the sweetness, glucose being from three to four times less sweet than sucrose. The use of apple-jelly may be detected by a microscopical examination for starch, the apple being the only fruit which contains starch in appreciable quantities. The value of this test is, however, limited by the fact that the starch disappears very rapidly with the ripening of the fruit.

The color of the diluted jelly is first destroyed by treating it at the boiling-point with a little diluted sulphuric acid and potassium permanganate, which does not attack the starch, and then testing with iodin. Excessive quantities of starch will naturally show that it has been added directly; but this form of adulteration is not generally resorted to.

Confectionery.—Probably one of the most extensive uses of glucose is in the manufacture of candies and confections, and its addition can hardly be styled an adulteration. Other constituents are sucrose, invert-sugar and gum, and a separation of these carbohydrates is very difficult, and possesses no value in the judgment of the materials. Glucose is used most largely in the manufacture of transparent candies, as these cannot be prepared with cane-sugar.

Glucose and Dextrose.—The most recent German food-regulations permit the addition of glucose or dextrose to foods and wines, provided they are technically pure, or, in other words, do not contain more traces of sulphuric acid or non-fermentable constituents. These restrictions are due to the fact that the non-fermentable substances, among which may be mentioned amylin and gallisin, are dangerous to health, but it must be stated that this point has not been

definitely decided. Analyses of glucose or dextrose are therefore frequently required which, with reference to the carbohydrates, consist of a gravimetric determination of the dextrose before and after treatment with hydrochloric acid, the latter converting dextrin into dextrose. The dextrose derived from the dextrin is obtained by difference and calculated to dextrin by the factor 0·9. The non-fermentable constituents are determined qualitatively by the fermentation method. When these are present it is necessary to deduct the dextrose which they yield by inversion from the total to obtain the true percentage of dextrin.

Dextrose generally contains from 65 to 75 per cent. of dextrose and 5 to 15 per cent. of dextrin and unfermentable bodies, while glucose contains from 35 to 45 per cent. of dextrose and about 40 per cent. of dextrin, etc.

Beer.—The most important material used in the manufacture of beer is the barley which contains the starch from which the sugar necessary for the fermentation is derived. A barley containing a large percentage of starch is therefore preferred by brewers, and it is customary to determine the amount present as a means of judging the value of the cereal. The analysis should always be made by the diastase method, whereby the error which is introduced by the hydrolysis of the insoluble carbohydrates, when methods depending on direct treatment with acids are used, is avoided.

During the malting process, a ferment, diastase, which has the property of converting starch into sugar, in the presence of water, is formed in the grain. To properly judge the malt, it is therefore necessary to determine the time required for complete saccharification. The method used is as follows:

Fifty grams of the ground malt are mixed with 200 cubic centimeters of water at 45° C. and kept at this temperature for an hour. The temperature is then increased to 70° C. at the rate of 1° C. per minute, and the mash is kept at this temperature and tested with an iodin solution every five minutes until only a light red or yellow to brown reaction is obtained. The time of saccharification is calcu-

lated from the moment when the temperature reached 70° C., and the mash must be stirred slowly during the whole process. The mash is then mixed with 200 cubic centimeters of water, cooled rapidly to about 15° C., the weight increased to 450 grams by the addition of water and the wort obtained by filtration. The density of the wort is determined at 15° C. and the total extract calculated by means of a table prepared by Windisch.* The total extract in the air-dry malt is then calculated according to the formula

$$p = \frac{e}{100 - e} \times (W + 2H)$$

in which p = total extract in air-dry malt,
e = total extract in the wort,
W = moisture in the malt,
H = weight in grams of the water added.

The sugar is determined gravimetrically as maltose in the diluted wort, using Wein's method, and the proportion of maltose to non-maltose is then obtained. The time of saccharification varies from fifteen to forty-five minutes for a good malt. The total extract should equal from 74 to 82 per cent., and the proportion of maltose to non-maltose should be about 1 : 0·5.

The carbohydrates present in beer are traces of maltose which have escaped fermentation and achroodextrins [Achroodextrin I and II (Lintner) Achroodextrin III (Prior) and possibly also Achroodextrin IV, Maltodextrin II (Baker and Link)] all of which exert a specific reducing action on an alkaline copper solution.

A determination of the maltose, therefore, always includes the reducing value of the dextrins, but it has become customary to simply determine the total reducing power of a beer, stating this in terms of maltose.

The dextrins are determined by inversion with hydrochloric acid, the total dextrose being estimated and the dextrose equivalent to the maltose previously found being deducted (maltose × 1·052 = dextrose). The remaining

* Bujard and Baier, "Hilfsbuch für Nahrungs- mittelchemiker," p. 198.

dextrose is calculated to dextrin by the factor 0·925. The amount of dextrins present in beers generally amounts to about one-half the total extract.

Barley substitutes are frequently used, especially in the manufacture of light beers, and among these may be mentioned rice and glucose. It is very doubtful if the substitution of another cereal for barley can be detected with any certainty. The examination for glucose is based, as in all other cases, where this adulterant is used, on the presence of the unfermentable constituents. The method of Haarstick is generally used, according to which the beer is evaporated to a thin syrup, from which all constituents precipitable by alcohol are removed, the alcohol recovered from the filtrate and the residue dissolved in water and fermented.

Malt Extracts.—These preparations have in recent years achieved considerable reputation as dietetic foods and are extensively manufactured. Their nutritive value depends chiefly on the soluble carbohydrates present, which vary with the degree of sacchrification to which the malt has been subjected. According to Dieterich, a good malt extract should contain from 62 to 67 per cent. maltose and from 2·5 to 4 per cent. dextrin. The maltose is determined with sufficient accuracy gravimetrically as described under "beer." The dextrin is most conveniently estimated by deducting the sum of maltose, protein and ash from the total solid matter. It may also be determined by precipitation with an excess of absolute alcohol. The maltose is precipitated at the same time and the precipitate must be dissolved in water and the reduction determined before and after inversion, the dextrin being obtained by difference.

The addition of cane-sugar to malt extracts should be considered an adulteration. The quantity present, when such an addition has been made, is such that it can be estimated with sufficient accuracy by determining the reducing sugar before and after inversion, although absolute results are impossible, owing to the presence of dextrin, which also suffers at least partial hydrolysis.

Wines.—The proper judgment of wine, even with the aid

of a complete analysis, is one of the most difficult problems presented to the food chemist, and requires an extensive experience and thorough knowledge of the composition and characteristics of the various kinds of wines, and of the variations existing between successive vintages of the same wine. The chief application of the results obtained by the determination of the sugars present in a wine is the detection of the method of treatment known as "gallizing," which is extensively practised by many winemakers. The composition of the must obtained in poor grape years is often such, with reference to the amount of sugar and free acid present, that a palatable wine can only be obtained by adding a certain quantity of sugar, either in the form of cane-sugar, invert-sugar or pure dextrose. A normal must will contain about 24 per cent. of sugar and 5 per cent. of free acid, but in poor years the latter will amount to as much as 16 per cent., and this will then be decreased by dilution with water, the quantity of sugar necessary to proper fermentation being added. The sugar required is usually calculated by multiplying the sugar-content of the original must by a factor obtained by dividing 100 by the volume of the diluted must. The German laws relative to the addition of sugar for the purpose of increasing the alcohol-content and masking the acidity of a wine, permit the use of technically pure cane or beet-sugar (not more than 1 per cent. non-sugars), of invert sugar prepared from technically pure cane or beet-sugar and not containing more than 20 per cent. of moisture, and of starch sugar (99·64 per cent. dextrose), but the addition is in general limited so that 100 cubic centimeters of wine shall not contain less than 1·50 grams total extract, 1·10 grams extract less non-volatile acids, 1·00 gram extract less total free acids, and 0·14 gram ash.

Frequently the "gallizing" is carried to the point where the manufacturer is forced to increase the total extract by the addition of gum or dextrin to the finished wine. The carbohydrates, which must therefore be determined in a wine, are invert-sugar, sucrose and dextrin, and, if indicated, an examination for the non-fermentable constituents of commercial glucose.

Another form of adulteration which is extensively practised and frequently very difficult to detect, is the preparation of wines from the pressed grapes, called petiotization. The pressed grapes are mixed with a solution of sugar, to which some tartaric acid has been added, and are then fermented. The resulting alcoholic fluid is improved as required by adding acid, glycerol, coloring matter, etc. These wines often have a good color and bouquet, and in many instances cannot be distinguished from pure wines except by a very thorough and careful determination of all constituents. A determination of the sugars is generally of very little value, as it gives no clue as to the source of the wine. The use of commercial glucose can be detected by the polarization after fermentation.

A pure, fully fermented wine is generally optically inactive or only slightly levorotary, a dextrorotation being a rare exception. The direct polarization is, however, not positive proof of the absence of an adulteration, as sucrose and invert-sugar or the non-fermentable dextrorotatory constituents of glucose and invert-sugar may be present in such proportions that the wine exhibits no rotation. The former condition is detected by determining the invert-sugar gravimetrically before and after inversion, the invert-sugar due to the sucrose being obtained by difference and calculated to sucrose by the factor 0·95. In the latter case, it is necessary to subject the wine to fermentation according to the following method:

"De-alcoholize 200 cubic centimeters of wine by evaporating to about one-fourth its volume, and add enough water to the residue to make its sugar-content less than 15 per cent. Add 2 or 3 grams of compressed yeast; let stand at about 25° for three to four days, when fermentation will be complete.

"Evaporate the fermented liquid in a porcelain dish to a thin syrup, after the addition of a little sand and a few drops of a 20 per cent. solution of potassium acetate. To the residue add 200 cubic centimeters of 90 per cent. alcohol with constant stirring. Separate the alcoholic solution by filtration and evaporate until about 5 cubic centimeters

remain. Mix the residue with washed boneblack, filter into a graduated cylinder and wash until the filtrate (cooled to 15°) amounts to 30 cubic centimeters, When the filtrate shows a dextrorotation of more than 1·5° it indicates the presence of the unfermentable constituents of commercial glucose."

Other conclusions with reference to the polarization of a wine are:

A dextrorotation may be due to cane-sugar which was added previous to fermentation. This may be detected as just described, or by means of a polarization before and after inversion; but when the invert reading exceeds + 0·3 Wild, the presence of glucose is indicated and the wine must be fermented and again polarized.

A slight levorotation may be normal and may also be due to the presence of cane-sugar, a portion of which has been changed into invert-sugar by the organic acids always present in wine. A wine of this kind will show an increased rotation after inversion.

A high reducing power may be due to the presence of invert-sugar, of dextrose, or of both. When only invert-sugar is present, the wine will be levorotatory—dextrose alone will produce a dextrorotation; and when both are present, the proportions may be such that the wine is optically inactive. The last condition may be detected by polarizing the wine at 87° C., at which temperature the rotatory power of invert-sugar practically equals 0, while the dextrose is not affected.

The general conclusions to be drawn from these data may be summarized as follows:

(*a*) When the wine contains less than 0·1 gram reducing sugar in 100 cubic centimeters, and is either optically inactive, slightly levorotatory, or has a dextrorotation not exceeding 0·3°, the absence of sucrose and of commercial glucose is proved.

(*b*) When the wine contains less than 0·1 gram reducing sugar in 100 cubic centimeters and has a dextrorotation of 0·3° — 0·6°, the presence of dextrin is indicated and the wine should be examined accordingly, and also for the unfermentable constituents of commercial glucose.

(*c*) When the wine contains less than 0·1 gram reducing sugar in 100 cubic centimeters and has a dextrorotation of more than 0·6°, it must be examined for dextrin and, if this is present, also for the unfermentable constituents of glucose. When dextrin is absent the wine contains the dextrorotary residue due to the addition of glucose before fermentation.

(*d*) When the wine contains more than 0·1 gram reducing sugar in 100 cubic centimeters, it must be examined for glucose.

Dextrin or gum arabic are sometimes added to wines for the purpose of increasing the total extract so as to bring it within the limits found in the normal product. An addition of this kind can be detected qualitatively by mixing the wine with two and one-half times its volume of 96 per cent. alcohol which, in the presence of gum or dextrin, causes a tough gummy precipitate. The adulteration may then be determined quantitatively by concentrating the wine to a small volume and precipitating with an excess of alcohol. The precipitate is collected, re-dissolved in water and inverted by means of hydrochloric acid, the reducing sugar being determined in the final solution and calculated to gum or dextrin by the factor 0·9. Pure wines will yield only traces of reducing sugar.

Sweet Wines.—The judgment of sweet wines is an extremely unsatisfactory subject, owing to the variety of methods by which they are prepared; and a discussion of the composition of the many types found on the market is impossible within the scope of this paper, as may be shown by quoting the general principles followed in the preparation of these wines, which are given by Elsner, "Die Praxis des Chemikers," p. 396, as follows:

1. (*a*) By fermentation of the must obtained by concentration of the juice of the partially dried grapes.

(*b*) By fermentation of must prepared by the extraction of raisins with must or diluted wine.

(*c*) By fermentation of a must which has received an addition of concentrated must.

(*d*) By the extraction of raisins with wine.

(*e*) By mixing must with wine.

2. By the addition of alcohol to the must while in the process of fermentation.

3. By the addition of varying quantities of cane-sugar, dextrose or invert-sugar to the must.

In the German wine laws these wines have appropriately been given a separate position and are styled "dessert wines," whereby they are distinguished from "medicinal wines," the latter being specially described as the product from pure grape juice, while in the former the use of raisins is not considered an adulteration. All sweet wines, with the exception of such wines as Malaga, sherry and Marsala, contain large quantities of reducing sugar, owing to incomplete fermentation, and the chief point to be decided by the chemist, with reference to the carbohydrates present, is the addition of cane-sugar, invert-sugar or glucose, it being manifestly impossible to express any opinion as to the origin of the wine, even with the aid of most complete analytical data. The polarization of the wine before and after inversion has very little value. Invert-sugar cannot be detected in this manner, as there is no change in the polarimetric reading. Cane-sugar can only be found in isolated cases, because it suffers rapid inversion during the fermentation of the must, although its presence may sometimes be shown when it has been added to the finished wine. The addition of glucose is detected by the polarization after fermentation.

According to König, the relation between the dextrose and levulose in such wines permits certain conclusions, these being present in a pure wine in practically the same proportions as in invert-sugar. A large excess of levulose indicates that the wine has been made by the fermentation of a concentrated must or by the interruption of the fermentation by the addition of alcohol. An excess of dextrose, on the other hand, may be due to the subsequent addition of an aqueous extract of raisins or grapes. A definite conclusion can, however, not be reached when these sugars are present in approximately the same amounts or when the levulose is only slightly in excess. Similarly,

the relation does not serve as an indication of the addition of cane-sugar or glucose previous to fermentation, as the dextrose derived from the former by inversion and that present in the latter are fermented as readily as the dextrose of the must.

Distilled Liquors.—The only addition to liquors which is of especial interest in connection with the subject under discussion is the use of caramel to impart an appearance of age to the beverage, and of small quantities of sugar to improve the palatability. This practice can hardly be considered an adulteration, except in the case of cognac, when the total extract should never exceed 0·5 per cent. A determination of the extract is the best means of detecting the use of caramel or sugar, as it can only consist of the substances extracted from the wood of the casks and the materials added for the purposes above stated. The use of caramel necessarily always introduces a small quantity of sugar, and the extract obtained from a colored cognac or sweetened liquor develops a very characteristic caramel odor when heated. Amthor's method,* which depends upon the precipitation of the caramel and subsequent conversion into caramelphenylhydrazin, may be used, although the accuracy of the method appears doubtful when we consider the exceedingly small amounts of caramel necessary to obtain the required depth of color. Thus, Fresenius found that a dark-colored rum contained only 0·34 to 0·68 per cent. extract. It is therefore evident that the addition of sugar or caramel to distilled liquors can be prevented most satisfactorily by fixing a maximum limit for the total extract present, but the composition of pure distilled liquors requires considerable further study before these can be established.

Omeis† has found several cognacs which were prepared with the addition of glucose; this being shown by the polarization after removal of the alcohol and fermentation with

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* Elsner: "Die Praxis des Chemikers," Ed. 7, p. 360.

† Omeis: "Ztschr. für Untersuchung der Nahrungs und Genussmittel," 1899, p. 703.

yeast. Cognacs are often found which possess a slight dextrorotation due to the presence of cane-sugar, but these all become levorotatory on inversion.

Coffee.—Cheap coffees are often glazed by the addition of sugar, dextrin or solutions of these substances during roasting, whereby imperfections are covered and the bean is made to resemble a more expensive grade. In some respects, however, the judicious glazing of coffee cannot be considered an adulteration, as a coating of caramel without doubt retains the volatile constituents of the bean and improves the aroma and taste of the beverage. The use of such substances for glazing is detected by shaking the coffee with cold water (20 grams coffee with 500 cubic centimeters of water at 15° C. for five minutes), and determining the quantity of organic matter removed by evaporating an aliquot portion of the filtered solution. The amount of sugar added by caramelization should not exceed 3 per cent.

The number of coffee adulterants offered either as such or in the form of mixtures with genuine coffee is legion, [illegible] cheaper grades of both whole and ground coffees sold in the American market are frequently adulterated—the former receiving an addition of artificial beans, while the latter are mixed with chicory, fig-coffee, crushed roasted cereals, etc. In most cases, when adulteration of this kind is suspected, the experienced microscopist has no difficulty in establishing its existence and the identity of the material, although he should always have at hand, for comparison and confirmation, a series of preparations representing the substances most frequently used for this purpose.

In some cases the microscopical examination may be profitably combined with a chemical analysis; thus, the presence of chicory may be detected by a determination of the reducing sugar present. Pure coffee contains only small amounts (0·5 per cent), while in chicory almost a third of the water-soluble constituents consists of reducing sugar, which is equivalent to about 20 per cent. Roasted cereals contain very little reducing sugar, but they may in turn be easily detected by determining the sugar found by hydrolysis; coffee yielding, on an average, 25 per cent., chicory 22 per cent. and roasted cereals 75 per cent.

The varying preparations which are sold extensively for the purpose of supplying a coffee-substitute which possesses the flavor of the genuine beverage, without its alleged harmful effects on the human system, are not to be despised. They are stimulating, nutritious and cheap, and should in time become the favorite drink of the poorer classes. Their value depends on the extent to which they possess the aroma and taste of genuine coffee and on the soluble carbohydrates present. If required, the soluble and insoluble carbohydrates may be determined as described under "Infant Foods."

Cacao.—The seeds of Theobroma cacao serve as a basis for a variety of important food preparations, chief among which are cacao, cacao powder and sweetened chocolate. Pure cacao is prepared by roasting the husked bean and pressing the mass into cakes while hot. Cacao powder is made in a similar manner; about one-half of the fat being removed by pressure. The ordinary sweet chocolate consists of cacao mixed with varying proportions of st... h and flavored usually with vanilla. It must be noted, how... that a guaranteed pure sweet chocolate should contain no starch other than that normally present in the cacao.

The chief adulteration of these various products consists in the addition of ground cacao shells or of starch or flour, a practice very generally applied to the cheaper grades. A careful preliminary microscopical examination should always be made whereby the presence of foreign starches is detected, the starch granules of the cacao being smaller than those of almost all cereals. The microscope may also be used in determining roughly the quantity of foreign starch present. For this purpose a number of preparations are made, using mixtures of pure cacao with 10, 15, 20 and 25 per cent. of starch, and the cacao to be examined is compared with these by counting the number of foreign starch grains present on a certain space. Zipperer has been able in this manner to detect the addition of one part of starch to 5,000 parts of cacao. When the addition of starch or flour has been shown microscopically, it may be determined by the diastase method after removing the fat. With sweet

chocolate it is naturally also necessary to remove the sugar, which is accomplished by extraction with 80 per cent. alcohol. The final result must be decreased by 15, which represents the average percentage of starch present in a pure cacao. The 80 per cent. alcohol extract may be used for the sucrose determination by removing the alcohol, dissolving the syrupy residue in water, and polarizing after clarification.

In connection with the detection of an addition of ground cacao-shells, the determination of the crude fiber or cellulose is often of value. A pure cacao contains from 3 to 4 per cent. or less, while the shells contain as much as 15 per cent. It is evident, therefore, that an addition of 10 per cent. of shells will increase the cellulose in the product by about 1·5 per cent. The addition of ground shells is the most frequently practised and at the same time most despicable fraud, as the shells have neither commercial nor nutritive value. Their presence must, without exception, be ascribed to intentional addition, as the separation of the bean from the shell is practically complete in factories equipped with modern machinery.

In judging a sweet chocolate, we may assume that a pure product contains, on an average, 50 per cent. of fat and non-sugars, and a figure much in excess of this indicates the addition of starch or flour, since it is possible to incorporate as much as 6 parts of flour for each part of fat present without materially changing the external appearance of the chocolate.

Spices and Condiments.—The adulteration of these necessary adjuncts to human foods is limited almost totally to the ground materials and is here very generally practised. In general, the analyst depends on a microscopic examination to detect the addition of foreign substances and does not attempt a quantitative analysis, it being sufficient to determine the presence and character of the fraud. An extensive trade is carried on in so-called "fillers," which consist of starch, flour, ground cereals and various other substances colored and flavored so as to resemble the spice with which they are to be mixed. Considerable experience

is naturally necessary to distinguish and identify the various materials which may have been added, as well as a knowledge of the characteristics of the starch granules which occur *per se* in the genuine spices.

Cinnamon is frequently adulterated with flour, bread-crumbs and sugar. The starchy substitutes are easily detected by means of the microscope. The presence of sugar may be shown by shaking the ground cinnamon with ether when the sugar sinks to the bottom. It may be determined quantitatively by polarizing an aqueous extract.

Cloves are occasionally adulterated by adding the so-called "mother cloves," *i.e.*, the partially ripe fruit of the clove-tree. These are recognized by the large amount of starch which they contain and which resembles turmeric starch very closely.

Pepper.—In the opinion of the dishonest spice-miller, almost any substance will serve as an adulteration of pepper. The pepper-shells and stems are extensively used, as also various flours, ground acorns, oilcakes, seeds, ground nutshells, etc., and the variety and extent of the sophistication is such that the microscopical examination is extremely difficult.

According to Lenz,* the addition of pepper-shells may be detected by determining the reducing sugar obtained by hydrolysis with hydrochloric acid. The various genuine peppers yield from 32 to 63 per cent., while pepper-shells only yield 11 to 13 per cent.

Jumeau recommends a determination of the cellulose for the detection of pepper-dust and pepper-stems. He found the black peppers to contain about 12 per cent., the white peppers about 4 per cent., pepper-dust, 28 per cent.

Paprika is frequently adulterated with various flours, bran, bread-crumbs, etc., which may be detected with the microscope.

Mace receives an addition of curcuma, flour, etc. Sugar may be detected qualitatively by shaking the spice with chloroform and determined quantitatively by polarization of an aqueous extract.

* Lenz, "Ztsch. f. anal. Chem.," 1884, 501.

Nutmegs are rarely sold in the ground condition. Excellent imitations have, however, been found which consisted of bread, clay and oil of nutmeg, and were covered with flour or chalk to make the resemblance more perfect. A microscopic examination readily reveals this fraud.

Saffron is often weighted with mineral substances, honey, sugar, gum or dextrin being added to obtain a more intimate mixture. The binding material can be removed by washing with lukewarm water and identified by means of the usual methods.

Cardamom seeds, when ground, are frequently mixed with ginger, flour, sugar, etc. The presence of ginger may be detected by the shape and size of its starch, the starch grains of pure cardamom seeds being extremely small.

Ginger is frequently adulterated with flour, sugar, etc. The methods of detection are similar to those previously given.

Mustard.—The chief adulteration of both ground and prepared mustard is the addition of rice or wheat flour, the color of the mixture being improved by the judicious use of turmeric. Such additions are readily detected by means of the microscope, as genuine mustard contains no starch. When a quantitative determination is desired, the analyst must take into consideration the possible presence of sugar, which is a constituent of some mixed mustards. This is most conveniently removed by diluting the mustard with water and washing thoroughly on a hardened filter, the starch being determined in the insoluble residue.

The presence of a certain quantity of flour in such mustards cannot always be styled an adulteration, as it may be added for the purpose of attenuating the zest of the condiment and in obedience to the demands of the purchaser. The manufacturer should, however, be forced to declare the extent of such addition, so as to prevent fraud; and it furthermore appears more proper to allow the consumer to determine the degree of dilution he desires and practice it himself. In ground mustard the presence of flour should always be considered an adulteration.

Other spices might be mentioned, but the materials used

for adulteration and the methods employed for their detection are practically the same as I have just described.

In conclusion, it is necessary to say that even with the amount of work done in the past, the results of which I have attempted to recapitulate in this paper, the study of foods with reference to the carbohydrates present has in many respects not kept pace with the advances made in other lines of food chemistry. Much future investigation will be required before the results obtained can be applied with absolute certainty, and until this end is attained the chemist will frequently meet with cases where the methods so far known have been shown to yield only approximate results, and where he is forced to rely upon his judgment in the choice of that method of examination which is most appropriate for the immediate purpose. In many cases the chemist is not justified in restricting his work to such precise determinations as are associated with other lines of other analytical chemistry, even though methods which permit this may be known. The food chemist must always take into consideration the fact that the exigencies of his work require methods capable of being carried out with such rapidity that they yield results, which, while they are only approximately correct, still serve the object of the investigation with perfect satisfaction. It must not be forgotten, however, that frequently cases arise in which he is required to apply exact methods. A wine may contain all the constituents usually found in the pure product and, furthermore, in fairly correct proportions, and may still be adulterated or purely artificial, when only a painstaking analysis of the ash will yield the information desired. It is evident, therefore, that the formulation of acceptable methods for all food analysis is an extremely difficult matter, and must be carried out with great caution, so as to avoid all errors which would naturally at an early date render the method inoperative. In Germany this work has been entrusted to a commission of experienced chemists, and the result of their labors is shown by the fact that the present food law contains specific regulations concerning the methods of food analysis, and limits with reference to certain constit-

uents as regards wine, butter substitutes, fats, poisonous dyes and utensils. It is to be hoped that a united effort may soon be made in this country whereby the adulteration practised so openly and extensively to the detriment of both the health and pocket of the public may be severely restricted if not completely stamped out. In this connection, exact methods for the determination of the carbohydrates and the proper interpretation of the results obtained will be of supreme value, and are a worthy subject for painstaking investigation.

BUREAU OF CHEMISTRY, UNITED STATES DEPARTMENT OF AGRICULTURE, Washington, D. C.

STASSANO ELECTROMETALLURGICAL PROCESS.

This process aims at replacing the heat of combustion of the coal in the ordinary metallurgy of iron by the electric arc, and should be advantageous in countries where fuel is costly and water-power cheap. The roasted and powdered ore is first of all passed through a magnetic separator in order to prepare a material rich in iron. This is then analyzed and the amount of carbon required for its reduction, calculated. The mineral is then mixed with the necessary amount of powdered wood charcoal and tar, whose percentage of carbon is known, and a slag-forming material, and made into briquettes. These are then introduced into the electric furnace. The chemical reaction is at first very lively, but becomes quieter after a time, and the amount of heat necessary continually decreases. A furnace of 150 horse-power yields in one and one-half to one and three-quarter hours nearly 30 kilograms of wrought iron. By varying the amount of carbon added according to the previously made analysis, it is possible to prepare a cast-iron with a certain fixed percentage of carbon. The plant at present working is at Darfo in the province of Brescia in Italy, and uses a fall of 30 meters of 5 cubic meters water per second.

FUTURE OF THE GAS-ENGINE.

In the opinion of Professor Thurston the gas-engine is a formidable rival of the steam-engine, and is capable of further development. Each has given a horse-power for about one pound of coal, and the efficiency of both, between the coal pile and the point of delivery, is about 20 per cent. The steam-engine, he says, has so nearly reached its limit that further progress under commercial conditions would seem to be very slow, but its range may be increased by employing very high pressures and superheating combined with them. In Sibley College work, 1,000 pounds per square inch have been used, and Professor Thurston expresses the view that twice that pressure may be successfully used eventually, or with sufficient experience in its management. These factors would raise the efficiencies nearly 50 per cent. and reduce the coal per horse-power hour to about three-fourths of one pound.

CHEMICAL SECTION.

Stated Meeting, held Thursday, October 2, 1902.

The Industrial Development of Indigo.

By J. Merritt Matthews, Ph.D.

The triumphs of chemical research in the fields of industrial life have attained such a height at the present time that the mind of the layman is no longer astonished at any marvel which may be accomplished. It requires a scientific mind and training to appreciate the numerous obstacles which must be overcome in the successful pursuit of an intricate chemical research. The outsider only sees the results in their entirety; the path by which that result was reached, though tortuous, dark and difficult to climb is not apparent except to the technologist.

Somewhat more than thirty years ago, when it was announced that the coloring matter contained in the madder root, and so extensively employed for the dyeing of red colors, had been made in the chemical laboratory from materials extracted from coal-tar, it elicted a great deal of surprise and comment, both from the laity and from men of science; and this surprise was furthermore increased when it was demonstrated that this red coloring matter, which became known as alizarin, could be manufactured not only in small experimental quantities in the chemist's test-tubes, but on a large commercial scale, and at a cost which soon drove the naturally occurring article almost completely from the market. Since then the development of the dye-stuff industry in the manufacture of numerous colors from coal-tar has had such rapid strides that people ceased to be astonished at results which would otherwise have been accounted marvelous; so that a few years ago, when it became known that the highly important coloring matter, indigo, had been successfully made from coal-tar, it only excited a passing mention, and indeed but few people outside of the profession were even aware that such a result

had been accomplished. And yet, the synthetic preparation of this dyestuff was one of the most far-reaching successes that chemical research has won. It was not the result of accidental discovery nor of haphazard experiment, but the outcome of twenty years of patient labor along well-defined lines of scientific development. The successful culmination of this work is a monument to the unwavering and strong-hearted faith of the chemist to the ideals of his science.

A word now as to what indigo really is. To the ordinary individual it stands for a certain blue color which is extensively dyed on all manner of textile materials. The technologist knows it as the most extensively employed dyestuff both of past eras and of the present time. It is derived from the indigo plant botanically known as *Indigofera tinctoria*, which means, "I make things of a blue color." This plant grows extensively in certain provinces of India and in various islands situated in the Indian Ocean, though it has been cultivated with a greater or less degree of success in numerous other localities. The extraction of the dyestuff from the plant is rather a complicated and wasteful process, and depends on fermentation rendering soluble certain ingredients held in the plant which a subsequent oxidation by the air converts into indigo. The dyestuff itself does not appear to exist ready-formed in the plant, but is contained therein in combination with a sugar-like body, the resulting compound being known by the name of *indican*. The plants are harvested at the proper time and the leaves and stems are immersed in water and allowed to macerate until an active fermentation has been engendered. When this process has proceeded to a sufficient degree the turbid greenish steeping liquors are drawn off into shallow tanks usually built of masonry. There the liquor is stirred up and beaten so as to expose it very thoroughly to the action of the air, after which treatment it turns blue, and on standing for some time deposits a blue muddy sediment which is collected, freed from excess of water by means of filter presses, and finally dried and pressed into blocks. This constitutes the natural unrefined indigo which formerly was

so largely brought into trade. It may be said that only from 0·2 to 0·3 per cent. of the weight of the plant is finally obtained as indigo.

The amount of coloring matter or indigotine in this crude natural product will vary from 10 to 70 per cent., according to the amount of accidental impurities, or the sophistications of unscrupulous dealers. Of late years, however, on account of the stern competition and the demand for greater purity, it has become the custom, to a great extent, to refine the crude indigo by chemical means, so that products can be obtained having as high as 90 to 95 per cent. of indigotine. The cultivation of the indigo plant, however, is a very precarious industry, so much depending upon climatic conditions for the success of the crop, in consequence of which both the quality and quantity of indigo produced were liable to great fluctuations from year to year.

It is a matter of some surprise that though indigo has been such an extensive article of commerce, and of almost universal use throughout the world, very little of scientific value was known concerning its chemical nature and constitution until comparatively recent years. The fact, however, is that its chemical constitution is a very complex one, and required the highest refinement of scientific knowledge to be brought to bear upon it before a clear insight into its molecular structure was attained. For the pursuit and final solution of the problem we are indebted to the indefatigable labors of Adolph von Baeyer, who for more than twenty years worked patiently upon this research, unraveling successfully, one after another, the many complexities with which the problem was surrounded.

It is historically interesting to know that from the study of indigo really sprung the early beginnings of the coal-tar dyestuff industry. As is well known, Unverdorben, in 1826, first discovered aniline in the products of distillation derived from indigo; and even further back than that, Haussmann, in 1788, prepared picric acid—really the first of the artificial coloring matters—from indigo, by treating the latter with nitric acid. The etymological derivation of the name aniline is also connected in an interesting manner

with that of indigo. The Sanscrit term for indigo is *nila* (signifying dark blue); this was adopted into the Portuguese under the word *anil*, from which in turn is derived the word *aniline*.

A full discussion of the chemical studies involved in the demonstration of the proper formula for indigo would engender too many complexities to be considered in this paper, and a brief review only of the principal points will be given here. As already mentioned, indigo in the plant exists in the form of a glucoside known as *indican*. This is capable of being hydrolyzed, by the action of dilute acids or of suitable enzymes, into indigotine and a glucose.

$$\underset{\text{Indican.}}{2C_{26}H_{31}NO_{17}} + 4H_2O = \underset{\text{Indigotine.}}{C_{16}H_{10}N_2O_2} + \underset{\text{Indiglucin.}}{6C_6H_{10}O_6}.$$

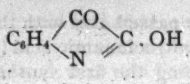
The empirical formula for indigo had been established by Crum and Laurent to be C_8H_5NO, and subsequently Sommaruga, by a study of its vapor-density, found that its proper molecular formula should be double that given by the empirical formula, or $C_{16}H_{10}N_2O_2$. Baeyer took up the investigation of its constitutional formula in 1865, and worked it faithfully to a successful conclusion. He found that indigotine was converted by oxidation in the presence of dilute alkalies into anthranilic acid; in other words:

$$C_{16}H_{10}N_2O_2 + 2H_2O + 2O_2 = 2C_6H_4\begin{cases}COOH\\NH_2\end{cases} + 2CO_2.$$

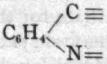
From this reaction it would seem apparent that the indigo molecule contained two phenylene groups, $C_6H_4<$, and that the nitrogen atom was probably an amido group or a residue of such. This reaction was also in keeping with the one whereby aniline was obtained by the destructive distillation of indigo with caustic alkalies, since the anthranilic acid, first formed as above indicated, would be further decomposed into aniline:

$$C_6H_4\begin{cases}COOH\\NH_2\end{cases} \longrightarrow C_6H_5NH_2 + CO_2.$$

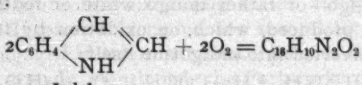
It was also found that a body known as isatin could be obtained from indigo by oxidation. The structural formula of this body was worked out carefully and found to be:



which was additional proof that the indigo molecule probably contained the group

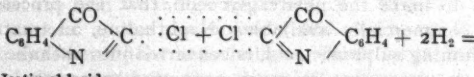


This opinion was still further strengthened when it was found that indol by simple oxidation could be converted into indigo:

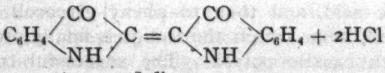


Indol.

The next step was the discovery that indigo could also be obtained from two molecules of isatin chloride by removing the chlorine, and as the new linking of the atoms of carbon would have to take place at the points occupied by the chlorine atoms, the following equation was reasoned out:



Isatin chloride.



Indigo.

In this manner the above formula was deduced for the proper structure of the indigo molecule, and all its subsequent reactions and methods of derivation have confirmed it as being true.

After its proper structural formula had been worked out, the next step was to prepare indigo synthetically. Its first synthesis had already been attained by Baeyer in the reduction of isatin chloride, as above indicated, but this was of no value from a commercial point of view. Several snytheses of minor importance were soon worked out in the succeeding few years, but they were of only theoretical

interest, and may be passed over with the bare mention that one was from ortho-nitrocinnamic acid (Baeyer, 1880). This was of interest as being the first synthesis to be patented. This body was converted into ortho-nitrophenylpropriolic acid, which was used to a certain extent in printing in connection with sodium xanthate for the production of indigo directly on the fiber. The first synthesis of real importance was that discovered by Heumann (1890), who used phenyl-amido-acetic acid (otherwise known as phenyl-glycocoll). It was found that this body, on fusion with caustic potash, yielded indigo—or rather indigo white or reduced indigo was at first produced, which, on oxidation by the air, was speedily converted into indigotine itself:

$$2C_6H_5 . NH . CH_2 . COOH + O_2 = 4H_2O +$$
$$C_6H_4\begin{<}{CO \atop NH}\end{>}C = C\begin{<}{CO \atop NH}\end{>}C_6H_4.$$

Although this reaction forms the basis of the present successful methods for preparing synthetic indigo on a commercial scale, yet it was not until it was found that naphthaline could be employed as a raw material from which to make the phenyl-glycocoll, that the process became commercially available. Naphthaline, on treatment with fuming sulphuric acid, is converted into phthalic acid, which by successive stages is converted into phthalimide, anthranilic acid, and then to phenyl-glycocoll ortho-carboxylic acid, from which the indigo is finally prepared by fusion with caustic potash. The successful commercial preparation of these successive bodies was only reached after tedious and thorough research on the part of specially trained chemists. Each step presented certain difficulties which had to be surmounted. A very large amount of fuming sulphuric acid was required, and the cost of this had to be brought down within certain limits. This led to the development of the contact process for the manufacture of highly concentrated acid. The Badische Anilin und Soda Fabrik, by whom this work was chiefly carried out, recover over 40,000 tons (in 1900) of sulphur dioxide formed in the reaction converting naphthaline into phthalic acid, and reconvert it into sulphuric acid by the contact process.

Also, monochloracetic acid had to be employed for converting the anthranilic acid into the phenyl-glycocoll compound, and it was found that this body was required of a very high degree of purity, which developed a process of making it from liquid purified chlorine and acetic acid, and in order to obtain it sufficiently cheap, the chlorine was prepared by an electrolytic process from salt, instead of the old methods of Deacon and Weldon.

The last few years (since 1897) have witnessed the successful exploitation of synthetic indigo upon the market on a large and continually increasing scale. Its manufacture has evidently proved lucrative, for several large dyestuff firms are engaged in its preparation. Besides the Badische Company, already mentioned, the Farbwerke Höchst are also large producers of indigo. These two firms for a number of years associated themselves in working out the synthesis of indigo, but since its commercial realization they have adopted certain modifications which give them slightly different methods of attaining the same end. The Société Chimique des Usines du Rhone, at Lyons, France, have also entered the field of indigo manufacture. This firm starts from toluene as the raw material and works up through ortho-nitrobenzaldehyde to indigo. Other large firms are also bending their efforts to obtain other processes to arrive at the same result. In consequence of all this activity on the part of the dyestuff manufacturers, and in view of the fact that the synthetic indigo is appearing in such large quantities on the market, and at a price which can undersell the natural product, we may soon look forward to the eventual total extinction of the natural indigo industry, in the same manner as the madder-root industry was quickly obliterated by the production of synthetic alizarin. Synthetic indigo appears to have all the essential qualities of the natural dyestuff, and can be prepared in a much purer state, so if anything it is really somewhat better in its quality than the natural product. And thus is recorded another triumph of chemistry over the clumsier processes of nature—and withal, that the very science which surpasses nature is but a science that nature makes!

A GREAT ENGINEERING FEAT COMPLETED.

With the laying, on the first day of the present month, of the last coping stone of the great dam across the River Nile at Assouan, the ancient land of the Pharaohs sees the completion of a national work, which is not only the greatest of its kind in existence, but in its beneficent results will probably outrank any scheme carried out in Egypt, either in ancient or modern times. The completion of this dam and a similar structure at Assouan will provide in the Nile Valley a vast reservoir capable of supplying over 1,000,000,000 cubic yards of water every year. The surplus waters of the river will be stored during the flood season, and then drawn upon for the irrigation of wide tracts of land which for many centuries past have lain waste for want of water. As a result of the new system of irrigation, there are extensive tracts of land which henceforth will bear two crops a year where formerly they bore but one; while the area devoted to sugar cultivation will be greatly increased. The Assouan dam itself is one of the greatest engineering works in existence. It is no less than 1¼ miles in length and it is pierced by 180 sluice-gates 25 feet in height and 7 feet in width, by means of which the regulation of the waters will be secured. The total cost of the two dams will be about $25,000,000, and the work has already proved itself to be an important economic feature in the life of the Egyptian people, for no less than 14,000 natives have found continuous employment during the progress of the work. The inauguration and rapid development of this great scheme has been due entirely to the enterprise of a Western race, entirely alien to the Egyptian people; and there is something peculiarly fitting in the fact that Egypt, which contributed so largely in its earlier days to the world's arts and sciences, should in these later times be thus richly endowed by the highly developed engineering skill of our modern civilization—*Scientific American.*

ALCOHOL MOTORS IN GERMANY.

The alcohol or "spirit" motor industry has been developing very rapidly in Germany. The chief advantage of these motors as compared with steam-engines are that they are always ready for work without a preliminary warming up; they can be filled up, oiled and started in from two to three minutes, there is no constant supplying of coal and water, no danger of fire or explosion, no consents required from Government authorities and no compulsory inspection. Their working is independent of the state of the weather, the "spirit" is easily obtainable in all districts, there is no smoke or smell, and the weight of portable "spirit" motors is about half the weight of portable steam-engines of equal power. The "spirit" for motors, containing 90 per cent. of pure alcohol, can be purchased at from 20 pfennige to 22 pfennige per liter (about 3 cents per pint), delivered at any station in Germany. The motors exhibited at an agricultural fair at Halle last year were from 1 to 25 horse-power. As regards cost, the Dürr Motor Company were exhibiting portable spirit motors of 6 to 8 horse-power at $1,000, 10 to 12 horse-power motors at $1,300 and 16 to 20 horse-power at $1,625. Of the tests made one trial gave a consumption of 0.92 pound of 86 per cent. spirit and 0.81 pound of a mixture of ⅓ benzol and ⅔ 86 per cent. spirit, in both cases per B.H.P. per hour.—*Iron Age.*

Mining and Metallurgical Section.

Stated Meeting, held January 8, 1902.

The Anthracite of the Third Hill Mountain, West Virginia.

By William Griffith, Mining Engineer.

SITUATION.

The Third Hill and Sleepy Creek Mountains are located in Berkley and Morgan Counties, West Virginia. They extend nearly north and south (N. 25° E.), the northerly end being about 13 miles west of Martinsburg, 7 miles east of Berkley Springs. Sleepy Creek Station, on the Baltimore and Ohio Railroad, is the nearest point by rail, being three or four miles north of the northerly end of the mountains, while Cherry Run Station (the junction point of B. & O. R. R. and Western Maryland R. R.) is 6 miles distant. This station is 124 miles by rail from Baltimore, 84 miles from Washington, 68 miles from Cumberland, 18 miles from Hagerstown and about 200 miles from Pittsburg.

TOPOGRAPHY.

As before stated, these mountains extend southward from near the Potomac River, having general direction of about S. 25° W. and are nearly parallel, being separated by the valley of Meadow Branch, which rises near the southerly end of the valley on the slope of Middle Ridge (a hill which gradually rises from the center of the valley, and increasing in height southward unites the two mountains). From Middle Ridge the Meadow Branch flows northward and empties into Sleepy Creek, a stream of considerable size, which drains the valley lying west of Sleepy Creek Mountain. The Back Creek Valley to the east of Third Hill is drained by Back Creek and its tributaries, and flows also into the Potomac west of Martinsburg. A good idea of the relative positions of these mountains can be obtained

MORGAN COUNTY
BERKELEY COUNTY
WEST VIRGINIA.
MARYLAND
Sleepy Creek Mountain
Third Hill Mountain
Back Creek Valley
Warm Springs Ridge
Potomac River
Opequon Creek
Shenandoah River
Martinsburg
Hedgesville
Bunker Hill
Gerrardstown
Falling Waters
Williamsport
Hagerstown
Boonsboro
Sharpsburg
Antietam Creek
Keedysville
Middletown
Frederick
Harpers Ferry
Shepherdstown
Kearneysville
Charles Town
Leetown
Smithfield
Duffields
Kabletown
Bardane
Berryville
Winchester
Stephens City
Middletown
Newtown
Kernstown
Opequon
Martinsburg
Hedgesville
Bunker Hill
Gerrardstown
Falling Waters
Williamsport
Hagerstown
Boonsboro
Sharpsburg
Antietam Creek
Keedysville
Middletown
Frederick
Harpers Ferry
Shepherdstown
Kearneysville
Charles Town
Leetown
Smithfield
Duffields
Kabletown
Bardane
Berryville
Winchester
Stephens City
Middletown
Newtown
Kernstown
Opequon

from the sketch map by noting that their general outline somewhat resembles a fish, Sleepy Creek Mountain forming the back, Third Hill the belly, and Middle Ridge uniting the two at base of the tail. Their southern extension, including Brush Creek Valley, forms the tail, while the nose and mouth are formed by the north end of Sleepy Creek Mountain and Short Mountain, the latter being a detached portion of the north end of Third Hill.

The crests of Third Hill and Sleepy Mountain are about 1,000 feet above the general level of Sleepy Creek and Back Creek Valleys and about 500 feet above Meadow Branch Valley, which latter, at Tom Meyer's, 11 or 12 miles south of the B. & O. R. R., is 600 feet higher than Sleepy Creek Station.

The coal beds, which are the especial object of this paper, are found in the rocks which flank the east side of Third Hill. At the southerly end, *i.e.*, near the fish's tail, the outcrops are near the crest of the mountain; but to the north the rocks containing them gradually separate from the main hill, forming Short Mountain, above mentioned. The space between Short Mountain and the main ridge is occupied by soft red shales, forming a sort of valley, in which several mountain streams have their source, which have cut channels or passes through Short Mountain, thus dividing it into a chain of short ridges lying end to end, parallel to Third Hill proper, and as the crests of these ridges are formed by the hard and almost vertical strata in which the coal is found, it will be seen that the coal outcrop runs lengthwise of the highest crest of Short Mountain and across the passes through which the Cherry Run and other brooks flow, as above mentioned, and that the coal beds are very accessible by water-level drifts lengthwise of the vein from the creek beds.

GEOLOGY.

A knowledge of the geology of this region is of the utmost importance in determining the value of the Anthracite coal in Third Hill; for if we know positively their geological position, we have gone a long way toward

determining their economical value. The following ideal cross section will serve to illustrate:

In the first place, we find that both Sleepy Creek and Back Creek Valleys are occupied by the soft red and yellow shales and black slates of the middle and upper Devonian measures, the lowest rocks of the series being in each valley farthest from the mountains in question, while the highest rocks of the Devonian Age (the red shales of the Catskill group, or No. IX of Pennsylvania Geological Survey), are found flanking the west slope of Sleepy Creek Mountain and the east slope of Third Hill. The crest of both of these mountains is formed by a ridge or spine of hard white and gray sandstone, being the lowest rocks of the sub-carboniferous or Pocono measures, and these same rocks form the mountain-sides sloping down to Meadow Branch.

The rocks in the crest and in the east flank of Third Hill and the Black Creek Valley are overturned or inverted, as shown by their decided dip to the east, while in Sleepy Creek Mountain and Valley the rocks are regular and dip also to the east. Thus we see that the two mountains are formed by a long, narrow, canoe-shaped trough or basin of hard Pocono sandstone, resting upon the soft red rocks of the valley. And it is through this basin that Meadow Branch flows, breaking its way through a precipitous gorge at the northerly end.

Now, while there are coal openings on the west side of Meadow Branch in a number of places, those in Third Hill are particularly interesting in this paper, and we will confine ourselves to the developments along its crest.

Anthracite coal has long been known to exist in Third Hill, and in fact has been found far to the southward and also to the northward in the same general range of Pocono rocks at various places. At Third Hill, however, more than any other one locality, the coal has been proved by many test-pits dug into the outcrop along the crest of the mountain for 12 or 15 miles, and while these provings have been very alluring to prospectors, and considerable time and money has been spent, both in shafting and boring with

diamond drills, as yet no coal beds have been found of sufficient value to warrant the expense necessary for their development. The true carboniferous formation, which includes the productive coal measures of Pennsylvania and West Virginia, are much higher in the geological series of rocks than the Pocono (in which the coal in question is found). And in Pennsylvania no Anthracite coal of workable thickness has ever been found in the Pocono rocks. It is true that in a few localities, notably in Kentucky and Tennessee, and in one or two special points in Pennsylvania, bituminous coal is mined in the low or carboniferous measures. At the same time, these beds are not so regular as to thickness and are more subject to faults and disturbances, and, consequently, are more costly to mine than beds of the true carboniferous age. As a rule, when bituminous coal exists, the measures are not much disturbed or distorted, and the coal lies flat or on moderate dips, very much as originally deposited; while in the case of Anthracite coal, the conditions are quite different, as it only occurs in highly disturbed measures, where the coal (originally supposed to have been bituminous) has been coked or distilled under the heat and great pressure, due to the distortion of the rock formation in which it exists The Anthracite beds of Pennsylvania are therefore found to contain more slaty refuse and are more subject to faulty squeezes, crushed coal, etc., than the bituminous beds of the same age. Again, the Pocono rocks are known to be false-bedded and much more irregular in their stratification and more liable to faults, crushes and other irregularities, than the rocks of the true coal measures.

As a result of the above facts and the known geological position of the beds of Third Hill, in connection with their steep dips (usually inverted) and the evident distortion and folding of the measures, we must expect to find the coal beds more or less crushed throughout the region, and in much the same state as the crushed and faulty coal of the Pennsylvania Anthracite beds. In addition to this, the beds would probably be found more irregular and erratic as to thickness and continuity, existing more or less as "pockets,"

and very uncertain as a basis upon which to make a large investment of capital necessary to development for railroad shipment.

The provings noted on Third Hill were made many years ago, the most recent provings west of Shanghi and near the source of Cherry Run, and it was impossible to get fresh samples of coal from the seam for analysis or tests. It is reported that a number of wagon-loads of coal were hauled away from the various shafts and sold, and found to give very good satisfaction as fuel, and apparently equal to Pennsylvania Anthracite. Analyses of fresh coal have been shown me, which average about as follows:

Volatile matter	about 10 per cent.
Fixed carbon	" 84 " "
Ash	" 6 " "

From this we should take the coal to be a semi-Anthracite, free-burning, white ash, approaching in quality the coals of Shamokin and Bernice, Pa., which are classed as Anthracites. It is probable that the above analysis is from picked samples of pure coal, and that the average of the vein would show much higher percentage of ash, owing to the bony coal and slate which would remain intermingled with it, even after careful preparation. The coal does not yield readily to the influence of the atmosphere, as is shown by the good condition of coal exposed ten or fifteen years at the proving shafts.

The rocks of the mountain in the south end, where the recent Shanghi provings were made, are much disturbed, and the coal bed in the proving shaft is inverted and the coal badly crushed.

At this point a distinct basin is found in the hard Pocono rocks near the crest of the mountain. This basin is about 500 feet wide, and shallow. The proving shaft was about 8 feet square, 50 or 60 feet deep, and sunk in the coal outcrop on the east margin of the basin. The writer was lowered into the shaft by means of a bucket and rope attached to the hoisting engine, and found the coal bed—which was supposed to be about 10 feet thick—much

crushed and faulty, as has before been mentioned, and practically worthless. Near the bottom of the shaft the bed seemed to be parted by layers of fire-clay or slate, and in worse condition than at the top. This shaft was shortly afterwards abandoned.

On the western outcrop of this narrow basin the rocks were regular, dipping to the east about 40°. A short tunnel had been driven westward into the hill, cutting a bed of coal about 2½ feet thick. The writer examined this vein, after having the tunnel cleaned out, and found that though the dip was regular and bed right side up, the coal was in much the same condition as in the shaft; and that while a small quantity had evidently been mined out and used locally by the farmers in the valley, the bed was virtually valueless for general development.

Previous to sinking the shaft above mentioned, much money had been spent in driving a tunnel horizontally into the east flank mountain, about half-way down, all the way through red rocks of No. IX, in hopes of cutting the vertical coal bed 200 or 300 feet below the surface. The tunnel (about 7 x 8 feet) was driven several hundred feet into the mountain, and at its end diamond-drill holes were bored horizontally 100 feet or more, until the water-pressure forced the drills out and stopped the future progress of the work. This tunnel would not cut the coal if it had been extended clear through the mountain, as it was probably far below the bottom of the shallow basin containing the bed. A diamond-drill hole had also been bored in top of the mountain, but outside of the coal basin.

As noticed above, as we go north from the Shanghi provings, the ridge containing the eastern coal outcrop gradually separates from the main ridge, and if the same basin-structure is maintained it becomes wider and deeper, allowing an area of red shale between Short Mountain and the main range, as priorly noted, and permitting the coal to cut down as low as the bottom of the lowest creek beds in the foothills near the valley. At the provings north of Shanghi the rocks seemed to be more regular, in some places vertical or with slight westerly dip, and not being inverted, owing

perhaps to their being higher and nearer to the summit of the overturn. The coal, except on the dumps, which had been taken from the shaftings, showed slightly better fracture, though much crushed and faulted. Further to the northward, in the vicinity of the lands near the head of Cherry Run, about the same conditions are found, the strata dipping about 80° to the eastward and inverted. The outcrop has recently been cut by a drift on the north side of Cherry Run Gap of Short Mountain, and more recently at a shaft in the gap southwest of Norrington's peach orchard. This shaft is about 5 x 8 feet, and it is said to be over 50 feet deep. Coal was struck about half-way down, and it is said to be about 4 or 5 feet thick. A number of tons were sold to the farmers nearby for upwards of $4 per ton, and was pronounced of satisfactory quality. Although this shaft was filled with water—and we were not permitted to examine the coal in places—we were able to judge of its structure and condition by the heap of coal, dirt, etc., still piled near the top of the shaft. It is unquestionably in the same crushed and faulted condition as found at every other point in the region where openings have been made.

As to the thickness and general condition of the coal in the beds north of Shanghi I cannot say, except from inference, as all the openings were long since filled. We noticed, however, that the pieces of slate exposed on the dumps had not the flat, laminated structure of the interstratified slate of the Pennsylvania Anthracite beds, but had the same shape and crushed appearance that characterized the coal, and was hard to distinguish from the coal, except by its greater weight or by breaking. This fact is an indication of the crushed, faulty condition of the beds, and of the great pressure to which they must have been subjected, as it is evident that the pressure was sufficient to crush not only the coal but the slate also, and force it out of its true stratified condition. The slate carries considerable iron and is much heavier than coal. Owing to this fact, it could be readily separated from the coal by the process of jigging common in Pennsylvania Anthracite regions. The writer had a proving-hole dug into the outcrop of a bed of coal in

Meadow Branch Valley, west of Tom Meyer's house, and found a 3½ to 4-feet thickness, lying in good position between regular dipping rocks, but the coal was of the same crushed and slippery character referred to above; and while the coal would probably burn good, the crushed condition would cause an excessively large percentage of fine coal, such as pea, buckwheat, and dust, which would much reduce the market value of the product, as would also its soft and friable nature; on account of which it could not stand much handling, but would readily crumble, causing much fine culm and waste.

Our investigations of this curious coal field have led us to regard the coal beds of Third Hill as a sort of natural curiosity or geological freak, and, owing to uncertainty as to thickness and continuity, and probable unreliable or "pockety" and faulty nature of the beds, their economical value is small. There can be no doubt that the above-described crushed condition of the coal beds extends throughout the region, including the deeper parts of the seam, far below the surface, as well as near the outcrop. Of course, if the coal beds in Third Hill were proved to be 3 or 4 feet thick or more, continuous and reliable, the large investment required to develop for railroad shipment would be justifiable, notwithstanding the crushed condition of the coal, for the location, excellent railroad facilities, and good market, at high prices, would go a long way toward counterbalancing the loss due to poor fracture or faulty coal. But to attempt to prove the reliability of these seams as to thickness, continuity, etc., would require a considerable expenditure, which would, in the writer's opinion, be very likely to result unfavorably.

SULPHURIC ACID BY ELECTROLYSIS.

Mr. Clinton Paul Townsend, in the *Electrical World and Engineer*, says: "Faraday and a host of subsequent experimenters have investigated the electrolytic oxidation of sulphur dioxide in aqueous solution, and have found that under normal conditions one-half the oxide undergoes oxidation to sulphuric acid at the anode, the remainder appearing as sulphur or sulphureted hydro-

gen at the cathode. In 1895, however, Dr. Leonard Wacker succeeded in rendering the oxidation quantitative by the concurrent use or production of carriers of oxygen, such as the persulphates, or even the halogens. Mr. Charles B. Jacobs now finds that the same result may be accomplished by a judicious application of the principle that oxidation is facilitated by a concentrated solution and low current density at the anode. In Jacobs' apparatus the anode is a porous composition through which the gas is injected in a continuous stream into the cell; and the anode area is thirty-three times that of the cathode. In the apparatus used the vessel is provided with horizontal electrodes and an interposed diaphragm. The porous anode constitutes a partition near the base of the cell, and into the lower compartment so formed sulphur dioxide is injected through the pipe, passing through the previous anode and undergoing oxidation therein. An outlet is provided for withdrawal of the sulphuric acid when the hydrometer shall indicate that the desired density has been reached. A refrigerating jacket is provided in order that advantage may be taken of the increased solubility of sulphur dioxide at 0° C.

"Jacobs, like Wacker, finds that by continuously injecting sulphur dioxide the sulphuric acid may be brought to standard concentration. While, as stated, the reaction, chemically considered, is quantitative, all of the sulphur dioxide being converted, the electrolytic efficiency is given as 54 per cent.; this result is attained with a potential difference of two volts and a current density of 15 to 20 amperes per square foot of anode surface."

THE METRIC SYSTEM.

One of the most interesting and important steps taken by the Colonial Conference that has just been sitting in London is the adoption of a resolution in favor of the metric system for all the British Colonies. Perhaps too much weight may be attached to this expression of opinion, but the Colonial statesmen met strictly for business, and would certainly not approve of such a change or policy unless they knew that it was in harmony with the sentiments of their people, whether in Canada, at the Cape, or away off in Australia and New Zealand. We are inclined ourselves to derive encouragement from this formal utterance, and to believe that in a short time necessary steps will be taken to give it force, wherever the state of the law so requires. The progressiveness of the British Colonies is a familiar social phenomenon, and their approval of the metric system will do much to assist in molding opinion and action in the United Kingdom, as it has already done in other matters. The benefit to international intercourse cannot be overestimated, and we may be sure that the Colonial officials did not go on record without adducing weighty arguments of that nature in support of their resolution. We are not aware what process exists for giving force and validity to these verdicts and decisions reached by the statesmen of Great Britain, but it is safe to infer that practical leaders of Colonial politics do not meet merely to pass resolutions. Their function is indeed growing rapidly into one of vast significance and utility, and it was never exerted to more beneficial unifying effect than in helping to create throughout the wide dominion of King Edward a simple, universal system of weights and measures.—*Electrical World.*

Section of Photography and Microscopy.

Stated Meeting, held Thursday, October 23, 1902.

A New Binocular Microscope.

By Frederic E. Ives.

It was once believed by a great many microscopists that the merits of the binocular microscope were such that it had "come to stay," and would grow steadily in popularity. On the contrary, it has come into such disrepute that several leading microscope manufacturers no longer even list binocular microscopes, and dealers who had them in stock have been closing them out at less than cost of manufacture.

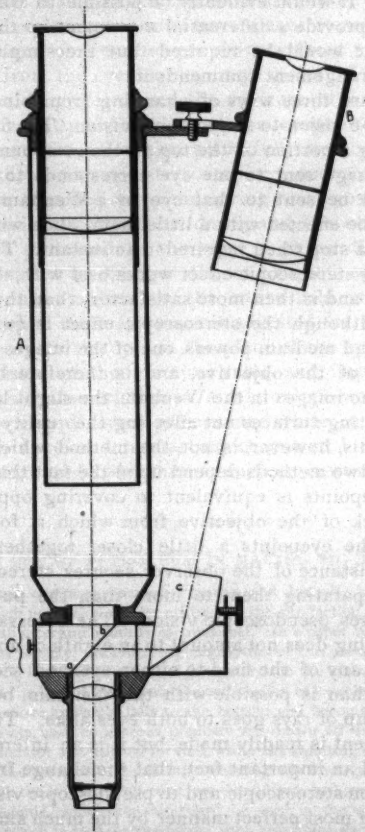
There are several reasons for this state of affairs, among which may be mentioned the following: (1) The Wenham, Nachet and Riddell binoculars all divide the light by prisms at the backs of the objective, with the result that the diffraction pencils which should define the most minute details of the right-eye image go to the left eye, and *vice versa*, so that neither image is sufficiently perfect when large aperture objectives are employed. (2) All binocular microscopes have long tubes, whereas most of the high-power objectives are now made to give their best results only with the short or "Continental" length of tube. (3) Owing to the unnecessary length of the mounts of most of the medium-power objectives, and the common use of revolving nosepieces, the position of the binocular prism is so far above the back lens of the objective that the best results are seldom obtained, even in the use of those powers with which the Wenham binocular is capable of giving satisfactory images. (4) Even those who would prefer to use the Wenham binocular for low powers cannot well do so except by having two microscopes, because it is important to have one with variable tube length.

It is evident, that in order to popularize the binocular microscope, it must first be freed from the defects which I have enumerated.

Some months ago I devised and constructed, and have since been using with considerable satisfaction, a binocular microscope which possesses the following advantages: (1) It is a "short-tube" microscope. (2) The parts which make it a binocular may be attached to an ordinary microscope without alteration. (3) It is not an expensive attachment. (4) It does not interfere with the use of the microscope as a monocular, with variable tube length. (5) It may be used either as a binocular non-stereoscopic microscope, or as a binocular stereoscopic microscope. (6) As a non-stereoscopic binocular, it sends to both eyes images practically identical with the single image of a monocular, no diffraction pencils being cut off from either image, and is as satisfactory with the highest as with the lowest powers, dividing the work evenly between the two eyes even when doing the most critical work. (7) As a stereoscopic binocular, it yields to both eyes images distinctly more perfect than either image in a Wenham binocular, and while giving true stereoscopic relief with medium and low powers, never exaggerates this effect, as the Wenham binocular sometimes does. As against these advantages may be placed the fact that it requires a little more skill to adjust it than the Wenham binocular; but it should not be at all troublesome to the expert microscopist.

The two attachments which effect this change in an ordinary microscope are, (1) a small prism box with society screw to fit the lower end of the microscope tube, and (2) an attachment to the upper end of the tube to carry the second eyepiece, with means for adjusting to suit different pupillary distances. The complete outfit is shown in *Fig. 1*, in which *A* is the microscope tube, *B* is the extra eyepiece and fitting, and *C* is the prism box. The prism box contains one compound cemented prism with transparent silvering on one of the inner faces, *a*, *b*, and a single prism, *c*. The dotted lines show the path of the axial ray, half of which is transmitted through the compound prism and the other half reflected into the prism *c*, and thence to the auxiliary eyepiece. The body of the prism *c* is extended in the direction of the eyepiece for the purpose of making the

optical length of both axial rays alike, so that matched eyepieces may be used; otherwise, the auxiliary eyepiece must



be a little longer in focus than the one in the main tube. Two adjustments are required—first, an adjustment of the auxiliary eyepiece to suit the pupillary distance, and then

an adjustment of the prism *c* to center the respective image, so that it corresponds to the image seen in the other eyepiece. It would evidently be possible to connect these parts and provide a differential movement, so that only one adjustment would be required; but the simplicity of the present arrangement commends it.

There are three ways of changing from binocular non-stereoscopic vision to stereoscopic vision. The first consists in covering a portion of the top of the compound prism, so that the image sent to one eye corresponds to the image that would be sent to that eye by a Wenham binocular. This may be effected with a little metal slide which can be pushed to a stop when required in an instant. This method of securing stereoscopic effect works best with short-mount objectives, and is then more satisfactory than the Wenham, because, although the stereoscopic effect is quite positive with low and medium powers, one of the images is made by the whole of the objective, and is therefore better than either of the images in the Wenham, the slight loss of light from reflecting surfaces not affecting the quality of the definition. This, however, is not the method which I prefer. The other two methods depend upon the fact that decentering the eyepoints is equivalent to covering opposite sides of the back of the objective, from which it follows that bringing the eyepoints a little closer together than the pupillary distance of the observer secures stereoscopic vision, and separating them to more than the pupillary distance secures pseudoscopic vision. The necessary amount of decentering does not amount to an eighth of an inch, does not cut off any of the field to either eye, and yields better definition than is possible with the Wenham, because the central group of rays goes to both eyes alike. This change of adjustment is readily made, but it is an interesting and, to my mind an important fact, that the change from stereoscopic to non-stereoscopic and to pseudoscopic vision can be made in the most perfect manner by the much simpler expedient of holding the eyes within or without the plane of the eyepoints. Owing to parallax of axes, if the adjustment corresponds exactly to the pupillary distance at the plane of

the eyepoints, the axial rays will be less separated below the plane of the eyepoints and more separated above that plane; and this is so far true, that with low-power objectives and 2-inch eyepieces one may have either stereoscopic or non-stereoscopic or pseudoscopic vision without moving the eyes to and from the eyepieces enough to cut off any of the field of view. I prefer to set the instrument for my own eyes so that exactly at the plane of the eyepoints vision is feebly stereoscopic; below that point, fully stereoscopic, and just above that point, non-stereoscopic; pseudoscopic vision may still be obtained by withdrawing the eyes until the field of view is somewhat cut down, and the objects may therefore be presented to the eyes in three distinct and informing aspects by changes almost as quick as thought. With high-power objectives, the entire field is seen perfectly only when the instrument is adjusted for non-stereoscopic vision with the eyes in the plane of the eyepoints.

A discussion of the practical value and importance of such protean characteristics in a microscope would doubtless disclose very diverse opinions, and while calling attention to their novel and interesting character, I must leave it to the future to decide whether such an instrument fills a real want.

THE USE OF PETROLEUM IN MAKING PIG-IRON.

Two Russian engineers, named Pitersky and Ivanoff, have devised a process by which petroleum can be utilized in the production of pig-iron in connection with a certain quantity of solid fuel. In a paper read before the Baku Technical Society, the following description of the process was given:

The solid fuel is placed in a special generator, into the lower part of which are introduced the heated gases from the combustion of petroleum. The fuel charged from above gradually falls to the bottom and becomes heated; dry distillation results, and the gaseous products are drawn off from the upper part of the generator and utilized for fuel, while the resulting coke continues to descend. The products of combustion entering the lower part of the generator pass over the incandescent coke, are deoxidized, and are thus available as reducing agents, which can afterward be used in the second furnace. This furnace, which is used for producing iron, resembles an ordinary blast-furnace, from which it merely differs in having a tube running down the center. The ore and fluxes are placed in the circular space between the walls of the furnace and the central tube, the latter being charged with a quantity

of coal sufficient to supply the iron with the required equivalent of carbon for converting it into pig-iron, also, if necessary, with fluxes for changing the composition of the slags. The circular space and the central tube are provided with covers to retain the gases. The heated reducing gases from furnace No. 1 are made to enter the lower part of furnace No. 2 through several openings. The gases at first melt the ore and slag. In ascending without changing their composition they convey their heat to the materials, and they begin to act chemically, by reducing the iron oxides, absorbing their oxygen, and becoming converted into carbonic acid. Although the gaseous medium gradually acquires pronounced acid properties, the effect of the carbonic acid is counteracted by the fall in the temperature. The spent gases collecting in the upper part of the furnace are utilized as fuel, the reduction process being preferably carried out by means of carbonic oxide. The central tube terminates at the place where a temperature of 900° C. prevails. The atmospheric medium at this horizon being of a reduced nature, the carbon dropping into the charge could only be utilized in combining with the iron to form pig-iron. The pig.iron and slags produced are tapped in the usual manner. The molten pig-iron from furnace No. 2 is run into the Bessemer converter. The pig-iron is converted into steel; the gases are led into generator No. 1 and serve for producing pig-iron in furnace No. 2.—*Iron Age.*

A NEW MOLDING PROCESS.

The steel-casting industry, which has made such wonderful strides in this country within the past decade, may be said to be still in its infancy, bright minds in the trade continuing to evolve new and still more wonderful ideas. One who has contributed in no small degree to this advancement is Frederick Baldt, Sr, general manager of the Penn Steel Casting Works, Chester, Pa. Mr. Baldt has discovered many new and important processes that have raised the standard of steel casting to a high point, but that he has not been content to rest upon these laurels won in the past is demonstrated by recent achievements. For months he has been engaged in developing ideas that have resulted in the introduction of a system of steel molding that promises to revolutionize the process.

Patents were recently issued to him that will materially simplify the molding of steel. The method consists in first making a master-mold from any pattern and then casting from this as many fusible patterns as may be required. This fusible pattern is then put into an iron box of suitable size, after which, by means of compressed air, the box is filled with molding-sand. The box is then run into the drying oven, where the fusible pattern is melted out. The casting is then made from the dried mold.

An important feature of this process is that it does away with skilled labor, the sand being conducted and driven by compressed air into all parts of the box and fusible pattern by either boys or laboring men. Since the castings are absolutely seamless and without fins, no chipping is required afterward. The process is also particularly applicable to the casting of chains and similar interlocked articles. By this process it is also practicable to produce articles in exact duplicate and in any number.—*Iron Age.*

The "Series-Vapor" and "Heat-Waste" Engines, as Supplementary to Single-Vapor Engines.

By R. H. Thurston,
Honorary Member of the Institute.

(*Concluded from p. 390.*)

Mr. Yarrow seems inclined to attribute the certainly great gain by use of the petroleum spirit to its small "latent" heat; but it is certain, as has been seen, that this is not the reason. It would seem much more probable that it is due to a more obvious difference in the physical properties of the fluids compared. In very small steam-engines, such as these, it is well known that the "cylinder-condensation" is enormously large and often amounts to several times the quantity of steam which would be demanded were this form of waste extinguished. Petroleum is a comparatively oily fluid and a most excellent non-conductor of heat; it is one of the best if not the only practically available insulator for high-tension transformers for the alternating electric current. Mr. Yarrow's experiences confirm the deduction, derived from many other sources and experimental investigations, that the extraordinary differences here referred to, which seem to be the greater, as the engines employed are smaller, are due to differences among these fluids in their capacity for producing, or for permitting, heat-exchanges between the working fluid and the inclosing cylinder-walls. Further direct investigation is required to settle this question; but all that can be gathered at present regarding the action of such fluids would seem to harmonize with that method of accounting for an undoubted superiority.

If this deduction is correct, it at once follows that such superiority will diminish as the size of engine increases and as this internal waste of the steam-engine thus diminishes. It is also the fact that, as superheating or other expedient

quenches this waste, the advantage of the more volatile and slowly conducting fluid must become less and may practically disappear. In any event, the work of Messrs. Haswell, Barrus, Magovern and Yarrow and others would seem to have established the existence of such differences as are here referred to, and that beyond question. Their deductions have been hesitatingly published and hesitatingly received by the profession; but this hesitation undoubtedly will be replaced by entire confidence, in the light of such facts as are here collated; while the deductions of Rankine and his followers, from purely thermodynamic considerations, must in that case fail, where the qualifying circumstances of actual work and of real heat-engine operation are taken into account.

Yet there still remain the two questions to be settled, and only by properly prolonged experience: (1) Whether these volatile fluids can on the whole, through their extra-thermodynamic properties, supersede steam as working fluid in even the smallest of simple engines? (2) Whether the "heat-waste-engine," with its volatile secondary fluid, is commercially a success?

The work of Professor Josse is the first of which we have record in which the modern requirements of scientific and complete thermal and dynamic, as well as thermodynamic, energy-transfers and transformations were completely exhibited, and such exact and full data secured as would permit the solution of the long-standing problem of efficiency to be positively and satisfactorily settled for the case studied. It was long ago fully demonstrated that the quantity of work derivable from the waste-heat of the steam-engine, through use of a secondary vapor of relatively high pressure, and thus capable of thermodynamic utilization of waste-heat of the primary machine, was sufficient to justify considerable additional expense in its production. The question was to this extent settled, and the remaining question is that of permanence, of utility, of safety and of ultimate financial gain when the life of the plant and its incidental and direct costs are taken into the account; for the so-called incidental costs of maintenance, replacement, accident and

repair are, in cases such as this, essentially important data which usually long remain undetermined.

The design, construction and adjustments of the binary engine employed in the case in hand were due to expert and scientific minds, and the immediate result of the first tests was the assurance that the gain in power by utilization of the ordinarily wasted heat of even a triple expansion steam-engine of good construction was sufficient to compel attention and probably to justify complete investigation. The outcome of the first series of trials was published at the centennial celebration of the Berlin Royal Technical High-School, Report No. II, 1899. The engine was of 60 to 70 horse-power, and it is reported to be, at last accounts, still satisfactorily in operation. A second engine of 175 horse-power was set in operation, May, 1901, which has given even better results, confirming the impressions made upon the expert investigators by the first machine.

The German experiments have been made with a binary-vapor system in which sulphur dioxide is the secondary fluid. This substance, commonly known as sulphurous acid, has been used to some extent in refrigerating machinery, though not nearly to the extent to which ammonia has been employed. Its properties are well known, and the needed physical data are established with ample accuracy for the purposes of the engineer.

Sulphur dioxide, at a temperature of 140° F., that chosen in many cases as on the whole satisfactory at the point of contact of the primary and secondary systems, exerts a pressure of 156·6 pounds per square inch, and at the average temperature of the cooling water employed in the steam-engine, about 60° F., 40·8 pounds. It rises to 50 per cent. higher figures, with 20° higher temperature, than of hydrant water in warm climates. Its pressures are something more than one-half that for ammonia at the same temperature. The relation of pressures and temperatures of the two fluids are exhibited in the accompanying diagram. (*Fig. 6.*)

This fluid is seriously obnoxious when leaking into the air and it is essential that, as with ammonia, every precaution should be taken to insure absolute tightness in every

vessel into which it is to pass. It is liable, when mingled with air and moisture, to take up oxygen, and to thus become injurious to the metal surfaces enclosing it, although quite free from this objection so long as pure and dry. On the other hand, it is oily in its nature and a good lubricant, and no oil or grease is needed to reduce the friction of rubbing surfaces in its presence. Another probably important and valuable property which it possesses, in common with some other available secondary fluids, is comparatively small susceptibility to the form of waste, "cylinder condensation," often very serious with steam.

Pressure curves of SO_2 vapors.

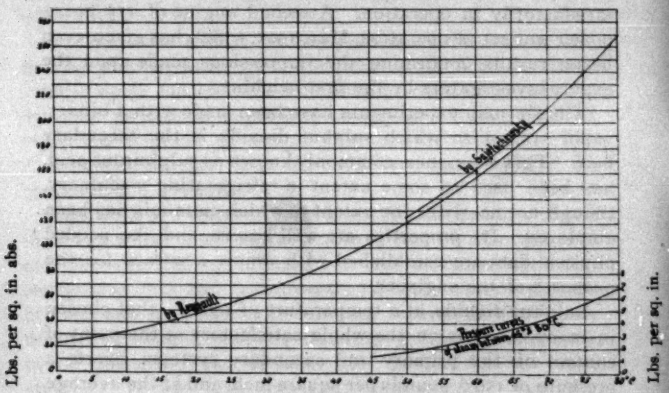


FIG. 6.—Steam and SO_2.

The Experimental Engine of the Berlin school is a triple-expansion machine, having a rated brake-power of 150 I. H. P. and a normal speed of about 150 revolutions per minute. Its cylinders are of, respectively, 270, 430, 675 mm. diameter and of 500 mm. stroke of piston ($10\frac{3}{8}$, $16\frac{15}{16}$, $26\frac{9}{16}$, and $19\frac{11}{16}$ inches). To this engine was attached the secondary system, a "cold-vapor engine," whose cylinder was of equal stroke and its diameter 266 mm. ($10\frac{1}{2}$ inches).

The details of construction were modified from those of the steam-engine, usually for the purpose of securing more perfect packing of rod and valve-stems, and the latter were made to rotate, rather than given a motion in the axial line, to better insure against leakage. The materials of construction are those usual with the steam-engine. The supplementary cylinder is designed for a maximum working pressure of 215 pounds per square inch. The piston-rod stuffing-box was especially designed to permit the use of grease as a lubricant and yet to avoid its working into the cylinder and through that into the condenser. No lubricant is required for the cylinder, the SO_2 sufficing. "Cylinder-condensation" occurred to such slight extent as to be quite unnoticeable, even at starting.

The "vaporizer" and the "condenser," introduced with the cold-vapor engine, are built, respectively, for pressures of 285 and 115 pounds, and contain 753 and 1,720 square feet of cooling surface. A safety-valve on the vaporizer leads the discharge to the condenser, and the safety-valve of the latter discharges into the open air. It is expected, however, to open very rarely. It was found that the vaporizer is capable of transmitting heat between the two fluids in contact with it about four times as fast, per unit of surface, than does the condenser; while the latter is so well designed as to transmit heat twice as rapidly as is usual in refrigerating apparatus in Europe. The proportions adopted were found to be more than liberal, and it will probably prove wise, as a matter of finance, to reduce them in later constructions.

The feed-pump set between condenser and vaporizer, and which demands about three-fourths of 1 per cent. of the power developed, is designed and built with especial reference to avoidance of either leakage or what corresponds in the steam system to "water-hammer." The fact that it must handle a fluid liable at any moment to approximate the critical state between liquid and vapor compels also special care and peculiar construction.

Regulation was effected through the governor controlling the high-pressure cylinder of the combination. It proved satisfactory.

Condenser. SO_2 Cylinder. Low. Intermediate. High pressure.

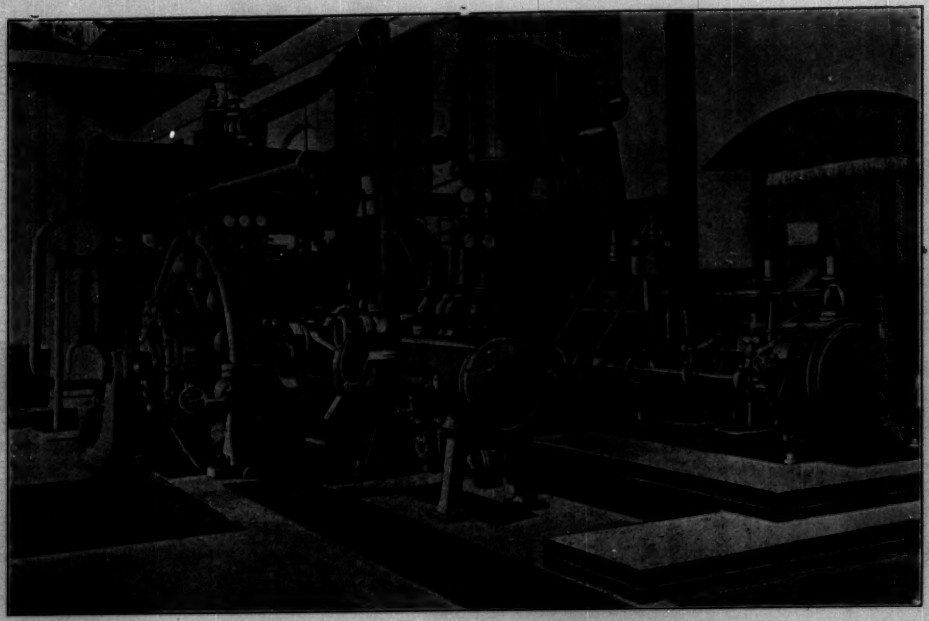


FIG. 7.—150 I.H.P. Engine of Technical High School.

In another engine, built for the oldest of the Berlin electric-lighting stations, the waste-heat engine is independent of the steam-engines. Rated at 175 I. H. P. it receives the exhaust-heat of steam-engines of 360 horse-power which demand in all about 18·35 pounds of steam per horse-power hour. It is so attached that the steam-engine may at any time be operated alone in case of accident or intentional detachment of the cold vapor engine. The combination was operated and tested at various times after completion; but the most satisfactory data for the purposes

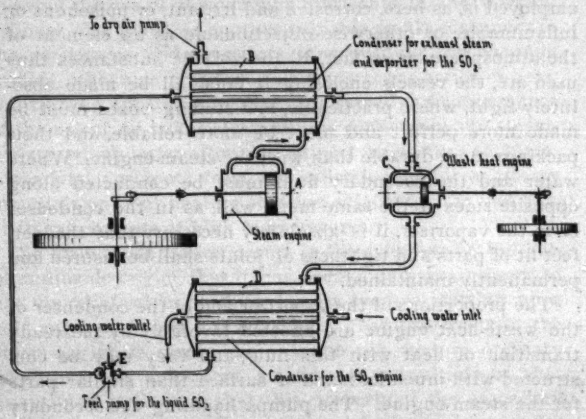

To dry air pump
Condenser for exhaust steam and vaporizer for the SO_2
Waste heat engine
Steam engine
Cooling water outlet
Cooling water inlet
Condenser for the SO_2 engine
Feed pump for the liquid SO_2

FIG. 8.—Scheme of binary vapor engine.

of the engineer were made after several months of working had brought the machine to something like a normal condition. The tests were made after the engine had become settled in its regime and in steady operation. The load was obtained from an attached dynamo and banks of incandescent lamps. The dynamo proved capable of an overload of 40 per cent. The quality of the exhaust-steam from the steam-engine was not determinable. All other data were probably as fully ascertained as could be desired.

The Use of Sulphur Dioxide, so long as free from air and

moisture, carries with it no objection on the score of injury to any part of the machine, whether iron or of other metal; and the construction may be similar in this respect to that of any other heat-engine. In those engines here described or referred to, the working cylinders are of cast-iron, and the minor parts of brass or bronze precisely as in the construction of the steam-engine. Modifications of size, proportions and details of design are, however, compelled by the change in the thermodynamic and physical and chemical properties of the working substance. Where the vapor employed is, as here, corrosive and irritant, or poisonous or inflammable, or otherwise objectionable as an element of the atmosphere, as, in fact, all the volatile substances thus used are, the vessels enclosing it must all be made absolutely tight, where practicable, and stuffing boxes must be made more perfect and must be more reliable, and their packings more durable than with the steam-engine. Where water and the secondary fluid must be conducted along opposite sides of the same metal wall, as in the condenser or in the vaporizer, it is absolutely necessary that the perfect fit of parts and tightness of joints shall be insured and permanently maintained.

The proportions of the vaporizer and of the condenser of the waste-heat engine are affected favorably by the ready transition of heat with this fluid, and they may be constructed with much less area of surface than similar parts for the steam-engine. The pumps handling the secondary fluid must be carefully designed for this special purpose, since they must usually be expected to work under a pressure which may in some cases be quite high, variations of temperature and pressure causing difficulties in operation, making the use of the "air-chamber" impracticable, but, on the other hand, this action giving an equivalent action, of which advantage may be taken to a limited extent. The secondary feed-pump brings no important load on the engine; its demand for power being reported at less than 1 per cent. of the total power.

The oily character of the secondary fluid, which is shared also by petroleum and probably some other available sub-

stances in some degree, is of peculiar value in the operation of the engine, for two reasons: the first being its insurance of freedom from friction without the introduction of oil into the working cylinder; the other, the reduction of internal thermal wastes by "initial" or "cylinder" condensation. The former reduces costs and difficulties of working; the latter the costs and waste of power-production. This latter property of these volatile fluids seems likely to prove one of the most important circumstances favoring their employment, either as primary or as secondary fluids. The ability to avoid the use of the common lubricants in the working cylinder also gives, as another valuable result, cleanness in the condensers and vaporizers, thus evading the common trouble, otherwise, of reduced efficiency in the action of heat-transferring apparatus, such as is observed as a consequence of the use of oil in the steam-engine condensers and steam-boilers, which latter often are subject to costly and sometimes fatal accidents from the collection of oil or greasy materials on their heating surfaces adjacent to the fuel-bed, or to gas-currents at high temperatures.

So little condensation occurs in the cylinders of the sulphur-dioxide engine that it has been found unnecessary to use the relief-valves on the cylinders even at starting up a cold engine. When it is considered that this waste in the steam-engine is rarely less than 20 per cent. in ordinary good practice, and often amounts to a multiple of that quantity, it is obvious that this property of the secondary fluid is one of great value and one which may even influence its more general adoption and possibly as a primary fluid in some cases.

The following is probably a sufficiently full abstract of the report made upon the combination of the 150 horse-power triple-expansion engine of the mechanical laboratory of the Berlin school with a 60 horse-power "waste-heat engine."

In this machine the high and intermediate cylinders are horizontal, tandem, and act upon the crank of the vertical low-pressure cylinder. The engine, supplied with a second crank—with rods, guide, and a frame with extension, for experimental purposes—the addition of a cold-vapor cylinder

was easy. The engine is provided with all experimental appliances, and may employ superheated steam, generated in an independent superheater close to the machine. The direct-driving dynamo was employed as load for the engine. The cold-vapor cylinder was attached to the frame. The vaporizer and condenser of the waste-heat engine were installed in place of the ordinary surface-condenser. The electrically-driven centrifugal pump, used as the circulating pump, and the vacuum pump were both retained.

The dimensions of the engines are:

Steam:	
High-pressure cylinder diameter	270 mm. = 10⅝ inches.
Intermediate " "	430 " = 16$\frac{1}{2}$ "
Low-pressure " "	675 " = 26$\frac{9}{16}$ "
Stroke of piston	500 " = 19$\frac{11}{16}$ "
Normal speed	150 revolutions per minute.
Vapor:	
Cylinder diameter	266 mm. = 10½ inches.
Stroke of piston	500 " = 19$\frac{11}{16}$ "
Speed	150 revolutions per minute.
Pressure assumed in design, pounds per square inch	215
Material of cylinder, cast-iron.	
Cylinder unjacketed and felted.	
H. S. of vaporizer, square foot	750
Cooling surface, condenser	1720
Pressure designed for maximum	285 for vaporizer.
" " " "	115 " condenser.
Material employed, iron.	

The Results of the Engine-Trials at the Charlottenburg school are condensed by the investigator into the accompanying table of data and resultant quantities. The steam was always superheated, except in test No. 8, when it was dry and saturated, affording a standard of comparison with the other cases. The temperature of the steam at the engine was usually about 300° C. (572° F.), that of the saturated steam 189·5° C. (373° F.), and the superheat 111° C. (200° F.). The temperature of the condenser of the steam-engine was adjusted so as to give satisfactory vacuum and at the same time a suitable vapor-pressure in the "vaporizer" and a good diagram at the secondary engine. The best work under these circumstances was done in Trial *B*,

TABLE VIII.—WASTE-HEAT ENGINE (AVERAGE VALUES).

Number of the Test			a.	b.	c.	3.	4	5.	6.	7.	8.	9.	10.	11.	
Date of the Test			25. 10. 00	21. 11. 00	23. 11. 00	12. 2. 01	14. 2. 01	14. 2. 01	15. 2. 01	15. 2. 01	16. 2. 01	20. 2. 01	26. 2. 01	21. 2. 01	21. 2. 01
Arrangement of Apparatus during the Test.			Steam engine working triple expansion									Steam engine working compound			
			Water from the condensation traps led into the vaporiser							into the discharge pipes		Water from the condensation traps led into the vaporiser			
			Superheated Steam									dry saturated	Superheated steam		
						with high vacuum								with small quantity of entraining water	at half Load
Speed — r. p. m.			139.6	136.3	143.5	137.4	145	145	148	148	149	137	148	137	146
Volts at Dynamo			210	189.5	210	191	209	212	231	230	230	208.5	235.8	210	230
Amperes from Dynamo			502	529	584	414.5	579	576.4	610	610	609.5	508.7	531	470	272
Steam Engine	Temperatures	Boiler steam — admission	279°	309°	310°	306°	302°	304°	310°	301°	189.5°	332°	326°	332°	330°
	Steam pressures	Inlet pressure — High-press. cyl. — lbs. per sq. in. above atmos.	136.5	156.5	158	156.5	156.5	156.5	156.5	158	156.5	166.5	163.7	156.5	156.5
		Percent vacuum in condenser	80	80.5	70	85	79.5	69	68.5	68.5	68.2	73	69.1	70.2	75.2
	Indicated output Horse power	High-pressure-cylinder	59.2	55.2	68.6	40.9	59.6	63.6	76.5	76.2	59.2	77.5	86.7	73.9	50.8
		Intermediate cylinder	43.3	35.7	43.2	31.3	42.4	41.1	42.5	45.0	47.3	—	—	—	—
		Low-pressure-cylinder	29.6	34.3	42.4	29.4	43.3	39.8	42.9	42.0	49.8	44.3	53.8	43.7	31.6
		Complete engine	132.1	125.2	154.2	101.6	145.3	144.5	161.0	163.2	156.3	121.8	140.5	117.6	82.4
	Steam consumption in lbs. per hour	Condensation from the vaporiser	1652	1405	1881	1465	1980	1994	2133	1775	2562	1649	1885	1612	1197
		Condensation from the steam jackets & receiver	—	—	—	—	—	—	—	367	—	—	—	—	—
		Total Condensation	1652	1405	1881	1465	1980	1994	2133	2142	2562	1649	1885	1612	1197
		per H. P. ind.	12.5	11.2	12.2	14.4	13.6	13.8	13.2	13.1	16.4	13.5	13.4	13.7	14.5
Waste-Heat-Engine.	Temperatures	SO_2 vapour Admission to cylinder	55.6°	56.5°	66.5°	50.4°	59.5°	69.5°	68.4°	70.5°	67.5°	67.1°	68.0°	67.9°	64.4°
		SO_2 liquid, outlet from Condenser	19.0°	18.8°	19.8°	18.0°	20.3°	19.8°	20.0°	18.7°	21.1°	18.1°	19.4°	24.0°	18.4°
		Circulating water — inlet	9.8°	9.9°	9.9°	10.1°	10.3°	10.1°	10.1°	10.1°	10.1°	10.1°	10.1°	10.0°	10.0°
		Circulating water — discharge	15.5°	15.7°	16.0°	15.7°	17.7F°	17.4°	17.46°	16.7°	18.44°	16.25°	17.4°	24.8°	17.2°
	SO_2 pressures (above atmospheric in lbs. per sq. in.)	in Vaporiser	132	128	172	110.9	142.2	187.7	186.3	192	180.6	177.7	183.4	180.6	164.9
		in Condenser	31.2	33.5	34.8	31.2	35.5	35.5	36.2	34.2	38	33.2	34.8	40.2	33.1
		Indicated	45.3	42.8	56.8	31.0	50.1	57.6	61.3	54.7	66.0	48.0	55.6	40.8	30.6
	Output — H. P.	in percent of steam-engine	34.4	34.2	37.0	30.5	34.5	40.0	37.8	33.3	42.1	38.4	39.5	34.8	37.2
	Consumption of waste-steam per I.H.P. per hour lbs.	Condensation from the steam jack & receiver. Taken in to the Vaporiser	36.5	28.8	33.2	47.3	39.5	34.6	34.8	—	32.5	38.9	34.4	33.9	39.5	39.1
		Led to the discharge pipes	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Combined Engine	Output — H. P	Indicated	177.4	168	211	132.6	195.2	202.1	223.2	217.9	222.3	169.8	196.1	158.4	113
		Effective	151.8	143.8	177.2	114.2	174.3	176.2	202.9	201.9	201	150.8	180.2	141.9	89.7
		Electrical	140.9	134	164.5	106.3	162.5	163.5	189.1	188.2	187.2	141.9	167.5	132	83.7
	Total steam consumption per hour — lbs.		1652	1405	1881	1465	1980	1994	2133	2142	2562	1649	1885	1612	1197
	Steam consumption per I. H. P. per hour — lbs.		9.7	8,36	8,8	11,05	10,12	9.86	9.55	9,85	11,5	9.7	9.6	10,22	10,6
	Quantity of circulating water in gallons	Total per hour	—	11 660	13 090	—	12 480	11 330	12 468	12 584	13 310	12 144	12 056	5 236	8 140
		Per I. H. P. per hour for the comb. engine	—	69.5	61.6	—	63.8	56.1	55.8	57.7	59.9	71.6	61.5	33.0	71.9
	Mechanical Efficiency	Electrical Output ÷ I. H. P.	79.5	80.1	78	80.4	82.8	81	84.5	86	84.2	83.5	85.5	83.5	74
		B. H. P.*) ÷ I. H. P.	85.5	86.2	83.8	87.5	89.1	87	90.8	92.5	90.5	89.8	92	89.8	79.5

*) Dynamo efficiency assumed 93 per cent.

when the steam-engine demanded but 11·2 and the combined engine but 8·36 pounds of steam per horse-power hour, the latter figure breaking the "world's record" of its date, while the former is remarkably good for the size and type of engine. In this test the "waste-heat engine" added 34·2 per cent. to the power obtained from the primary engine.

When working with saturated steam, these figures become, respectively, 16·4, 11·6, and 38·9; showing a gain by the use of superheated steam of about three pounds, maximum, or, in B.T.U., about 20 per cent. for the combined engines. The compound engine, with large drop between cylinders, gave as good results, on the whole, if we except the two tests, *b* and *c*, as the triple-expansion machine; indicating, we may perhaps conclude, that with superheated steam the type of compound is a matter of comparative indifference, and that the compound with large cylinder-ratio is practically as satisfactory as the triple. Incidentally, it was noted that the use of superheated steam in these engines produced some leakage past the steam-valves.

The first three trials were made in November, 1900, the others in February, 1901; the latter showing the effect of use.

On reference to the table of data and results, it will be seen that all the reported trials of this extraordinarily well-constructed and most skilfully tested machine are remarkable for their admirably high efficiencies.

The average results of the best seven trials with superheated steam were the following:

Indicated horse-power, triple-expansion steam-engine	146·4
Plus indicated power of the waste-heat engine	52·7
Total, combined engine	199·1
"Water-rate," steam-engine	12·80
Same for combined engine	9·43
Gain by waste-heat engine	3·37
Percentage of gain of power	35·1
Net gain in economy of power-production	26·3

The points at once attracting notice on inspection of the figures are the high efficiency of the primary, the large gain by progressive superheating to the moderate extent here adopted, the previously unobserved, though not unanticipated, fact that the combined engine profits even more by superheat than the primary, the extraordinary gain by only 20° C. of superheat, in cases *a* and *b*, the small influence of the vacuum variation in these cases, the correspondence of high efficiency of the primary with high efficiency of the combined engine, the gain of 30 to 40 per cent. in power while gaining 25 per cent. and more in economy, and the high mechanical efficiency of the combination, 86·2 in the case of maximum thermal efficiency and up to 92 per cent. in other cases; the electrical output being from 74 to 85 per cent. of the I.H.P.

Comparing these results with the corresponding ideal cases, which would, with a Carnot cycle, give the horse-power hour on about five, and with the Rankine or Clausius cycle, as a minimum, about 6 pounds of dry and saturated steam per horse-power hour, or with 5,000 to 6,000 B.T.U., it is seen that the delivery of the engine here studied is very much more satisfactory than the rival primary form, but that it nevertheless still leaves a considerable range for further improvement. Its efficiency as a thermal engine exceeds that of the primary in proportion to the gain in aggregate power, which is shown in the table to amount to from 30 to 40 per cent. The primary has an efficiency approximating 20 per cent., while the binary machine gives a combined efficiency of about 27 as an average. The net efficiency, thermal and dynamic, together, is thus about 23 or 24 per cent. That of the ideal cycle, as a purely thermodynamic system, for the observed range of temperature, is about 50 per cent., of which about 10 per cent. is due to the superheat obtained in the average case taken.

The best engines of the time, so far as investigation has gone, give a comparable efficiency, in the actual case, of slightly above 20 per cent. and, in the case of the Hall & Treat engine, with abnormal steam-pressures (300 to 600 lbs)

and a quadruple expansion engine, under exceptional circumstances, the ideal efficiency was 0·28; the ideal engine demanded 8,000 B.T.U. and 6·86 pounds of dry steam per horse-power hour, while the real engine did its best work at the lowest pressure and demanded about 225 B.T.U. per I.H.P. per minute, 13,500 per hour and 9·27 pounds of slightly superheated steam, developing but 11 horse-power with a mechanical efficiency of 87 per cent.*

In the engine trials reported, it was usually made a condition that the gain by the use of the secondary fluid should not be at the expense of the efficiency of the primary engine. The increased power and the gain in economy are thus measures of the advantage to be secured by the addition of a "waste-heat engine" to the ordinary steam-engine when the latter is itself a very economical machine and much more so than the average engine as constructed by even good builders.

In these trials it was incidentally noted that the best effect was secured when the steam-engine was operated with a somewhat imperfect vacuum, 70 per cent. or about 21 inches. Either a better or a worse vacuum reduced the efficiency of the combined engine. The gain in the steam-engine, operated independently, was but about 3 per cent. when the vacuum was improved from 68·5 to 92 per cent., 21 to 27 inches. The experience confirms the well-known principle, that with every engine the best vacuum is determined by the cost of its production as well as by the value of the gain secured by it.

The secondary engine was found to be subject to but slight loss by cylinder condensation; this is to be at least in part accounted for by the narrow range of temperature worked through, and probably also in part by the comparatively small susceptibility of the oily fluid employed to heat-exchange with the metal of the cylinder. The sensitiveness of the secondary fluid to changes in the temperature of rejection of heat from the primary engine is seen in

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* "Promise and Potency of High-Pressure Steam." "Transactions Am. Soc. M. E.," Vol. XVIII, 1896, No. 718.

the data furnished by these trials. The rejection of heat from the steam-engine, when its vacuum was held at 24 inches, produced a pressure in the vaporizer of the secondary machine of 156 pounds per square inch, while with a vacuum of 21 inches, the gage showed 199. It was also observed in all these trials that the transmission of the secondary fluid was impeded by friction in the piping and that it is desirable, in designing this class of machinery, that the velocity of flow through steam and exhaust-pipes and through valve-ports, should be low relatively to the rates of flow of steam in common practice. The section of the passages should be made proportionately large. This feature is economically important, and the adjustment of sizes of piping to maximum economical result is one of those problems remaining to be solved by experience.

It is seen, on reference to the results recorded, that the secondary engine added to the output about 1 horse-power for each 32 pounds of steam used in the primary per hour. The consumption of heat in the secondary was 7,800 calories per horse-power hour, which is excellent economy when the small temperature-range is considered. With high exhaust temperatures in the primary engine, the water of condensation may be used profitably as feed-water and the steam condensation from the jackets and receivers may be employed to furnish energy to the secondary, affording a very sensible advantage. Employing superheat in the steam-engine, the relative value of the secondary engine is increased, since this infers the rejection of the exhaust at a higher temperature, though in smaller quantity, than when using saturated steam. On the other hand, these trials throw into relief the fact that generally increased efficiency gained by one expedient makes unnecessary the employment of another, and the compound engine would seem to be usually a better primary than the triple-expansion under conditions approximating those here illustrated. This is shown in tests Nos. 9 to 12 inclusive; but just how far the relatively high cylinder ratio is secured by this cutting out of the intermediate cylinder of the triple to form the compound cannot be here determined, although it is clear that

the compound performed about as well as the triple under the conditions observed. It is further to be noted, however, that when cylinder condensation is extinguished by superheating, the performance of the two engines should be practically the same, the *raison d'être* of the multiple-cylinder engine having been thus removed and the advantages of the compound made simply those of kinematic action and those of construction due to the equalization of pressures in the cylinders and on the crank-pin, when expansion-ratios are high.

The low range of temperature of the condensing water infers a large volume; but it is obvious that the same would be true with similar conditions in the steam-engine. In so far as a larger volume is demanded, it is due simply to the fact that it may be profitable to secure a lower final temperature of rejection of heat from the system than from the steam-engine alone. The quantity used in these trials ranged from about 33 to 55 gallons per hour per I.H.P., while 40 gallons may be taken as the average consumption in the primary engine operated under usual conditions. The low temperature-range of the cooling water compels a corresponding large area of cooling surface, and both the vaporizer and the condenser have in these engines comparatively large size and volume as contrasted with similar constructions for handling steam. The proportions recommended, 5 to 7·5 square feet per I.H.P. in the vaporizer and 20 to 25 in the condenser, are enormously larger than the proportions adopted, for example, in marine practice for steam-engines of the highest class.

The accompanying diagram illustrates the distribution of working fluids in the triple-expansion system as supplemented by the waste-heat engine. This diagram was taken during the progress of Test No. 6, in which, while the lowest temperature of heat and fuel was not reached or highest efficiency attained, an excellent adjustment of the several elements of the combination was illustrated, and this combined diagram may be taken as a good exemplar of its class. The individual, separate diagrams for all four elements of the combination are seen in the succeeding figures, and are

those from which the combined diagram has been constructed.

The combined indicator diagrams here given exhibit the distribution of steam and that of the secondary fluid where the intermediate cylinder was cut out to form a compound with a secondary fluid auxiliary. The steam being moder-

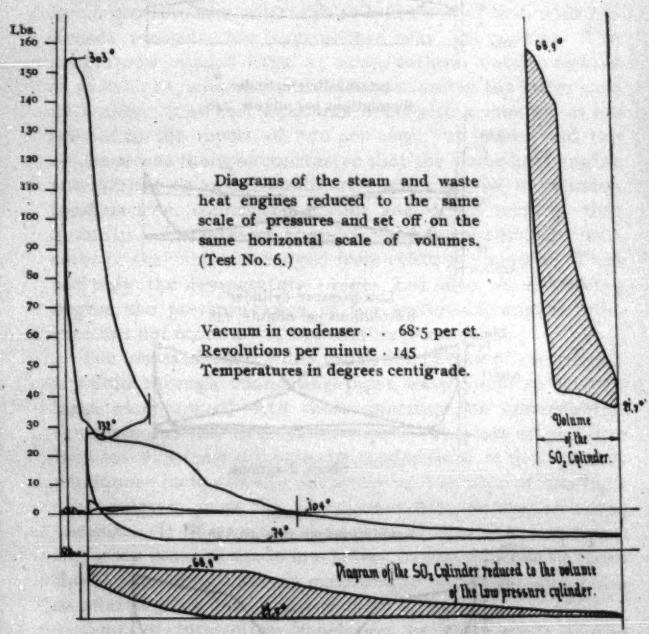
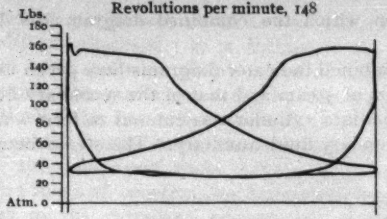


FIG. 9 —Combined diagram. Triple-test 6.

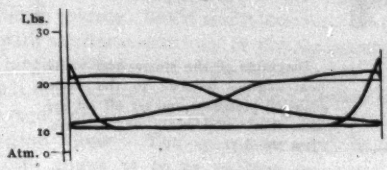
ately superheated, the consumption was practically the same with the compound as with the triple which it superseded, and the gain by the employment of the secondary fluid engine was no less.

Superheated Steam (300° C., 572° F.) was employed in the steam-engine, and it was endeavored to secure the highest

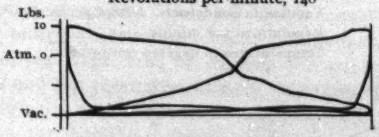
High-pressure cylinder
Revolutions per minute, 148



Intermediate cylinder
Revolutions per minute, 148



Low-pressure cylinder
Revolutions per minute, 148



Steam diagrams.

SO_2 cylinder
Revolutions per minute, 148

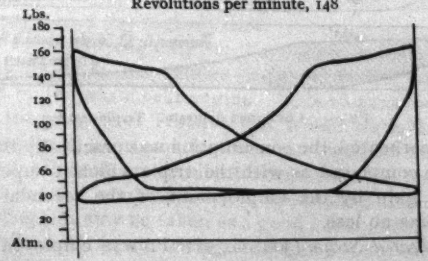


FIG. 10.—*SO_2* Diagrams.

practicable efficiency in that element of the combined machine. Its best work is reported to have been done with 11·2 pounds of steam per horse-power hour and while discharging 34·2 per cent. of its energy into the waste-heat engine, and thus reducing the consumption to the unprecedented figure of 8·36 pounds for the series-system. The steam-pressure was about 156 and, in another test, with 158 pounds pressure, the expenditure was 8·6 pounds. The usual result ranged from 9·5 to 10, without outside figures of 11 and 11·5, with reduced superheat, and in the latter case with none. The best work was done with a vacuum, as expressed in the report, of "70 per cent.," 21 inches, and the evidence was thought conclusive that the waste-heat engine was subject, in an extraordinarily small degree, to cylinder-condensation, confirming earlier and direct tests of that quantity. As between 21 and 24 inches vacuum, the pressures in the vaporizer ranged from 156 to 199 pounds. Thus not only the temperature ranges but also, in a striking degree, the pressure-range, of the waste-heat engine influence the net economy of the combined machine.

The losses of energy due to friction of flow of the secondary fluid through connecting pipes were found to be very large, as compared with those affecting the movement of the comparatively light water-vapor. The loss of pressure between vaporizer and cylinder ranged from 28 to 40 pounds per square inch, and the reduction of the area of the indicator diagram from the latter amounting to from 16 to 24 per cent. It follows that velocities of flow in the connecting pipes must be made much less, in practical use of these fluids, than for steam; an exceedingly important deduction as affecting the design of this class of engine.

Another interesting revelation by these tests is the advantageous effect of trapping the water of jacket-condensation into the vaporizer. This gain supplements, according to the reports, that derived from use of fedd-water, from the discharge of the vaporizer, at temperatures of from 140° to 160° C. (284° to 320° F.) at the boiler, affording a gain of about 7 per cent. over the steam-engine in ordinary cases.

Still another striking fact comes of the analysis of these

trials: Since the use of superheated steam reduces the cylinder condensation in the steam-engine, while, at the same time, the exhaust heat-waste slightly increases and the supply of heat-energy to the secondary fluid becomes somewhat increased, it follows that the use of superheated steam in this combination becomes doubly advantageous, instead

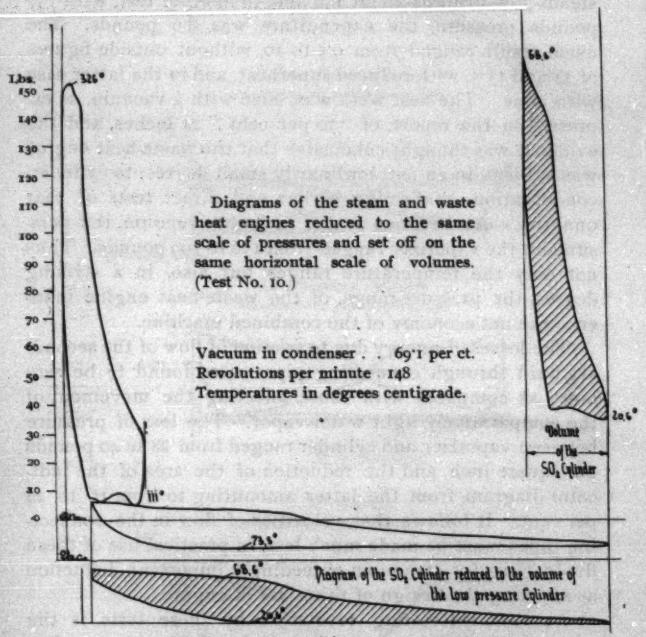


FIG. 11.—Combined diagrams. Compound.

of, as in the primary fluid alone, less advantageous with reduction of exhaust waste by the system of compounding. The triple-expansion engine is thus given a wider range of application commercially. Experiments show that, as was long since noted by the writer, in multiple-cylinder steam-engines, the employment of the one system, of reducing

wastes makes the use of the other less advantageous, and it is often questioned whether, with superheating, the compound, or even, with high superheat, the simple engine may not be financially more desirable than the triple or quadruple engine. In the present case, it was found that, when the intermediate cylinder was cut out, the economy of the resulting compound was as high, using superheating steam, as with the triple in use. It is concluded that, with superheating and a supplementary waste-heat engine, the compound engine is on the whole more desirable than the compound.

Economy is effected also in the use of cooling water. Since the utilization of heat is more complete, the rejected heat becomes less, and a smaller quantity of cooling water, if properly employed, is demanded for the binary-vapor engine. On the other hand, if cooling water can be obtained at small cost, it is possible to secure a larger gain by its free use, and it is advised to increase the supply 25 per cent. above that of the steam-engine as customarily operated. It is evidently advisable to investigate this question wherever proposing to employ the combined machine.

The indications of these investigations are that surfaces in the vaporizer and the condenser should be made about 7·5 and 20 to 25 square feet per I.H.P., respectively, when as effective as those here employed.

Considering the employment of the "cold-vapor engine" in other situations than as adjunct to the steam-engine, it is shown that the production of power, from the waste-heat of the chimney-flue of the steamboiler, with forced draught from the gases of the blast-furnace, and from the gas-engine particularly, it will be found that this choice of a working fluid for the heat-engine adapted to such special purposes may give large promise, especially as the "waste-heat engine" converts a large percentage of the heat supplied it into mechanical energy.

The larger the installation, the greater should be the advantage of the binary-fluid system.

The financial side of the question of adoption of this system has been somewhat illuminated by these investiga-

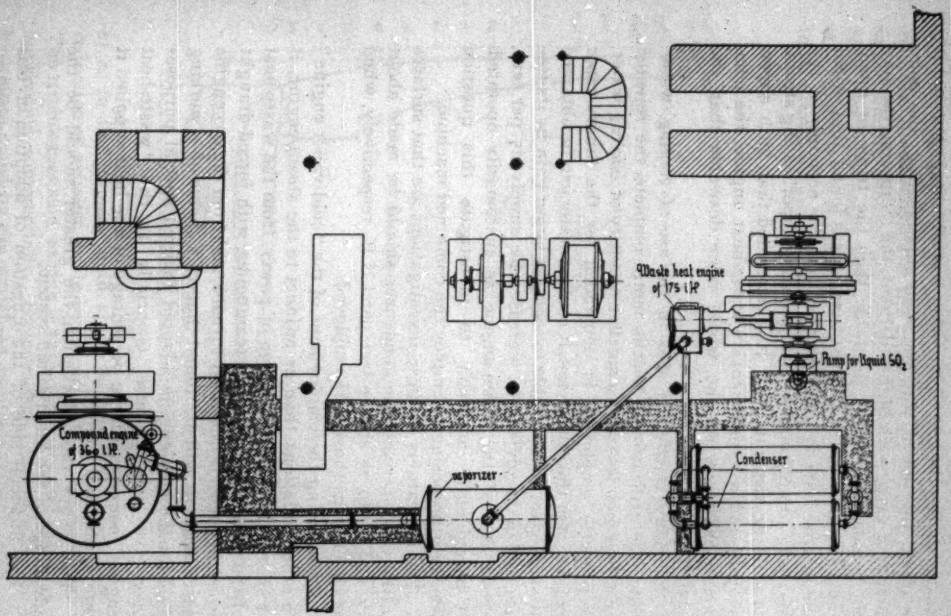


FIG. 12.—Detached "waste-heat engine."

tions. The costs of plants of 1,600 I.H.P. on this system and on the usual system of triple-expansion steam-engines, are reported to be, in Germany, respectively 212,000 and 206,000 marks—practically the same. Including costs of boilers and connections, the costs should be even less for the binary system, in consequence of the lesser boiler-power demanded. A similar comparison of costs of the binary-vapor and the corresponding gas-engine construction gives similar results for 175 I.H.P.; both falling under 50,000 marks for the whole plant ready for operation. The saving in fuel, in the former case, for 1,600 horse-power, is estimated at 6 per cent. on the first cost, allowing the consumption of the steam-engine to be, as is now guaranteed by builders, 10·05 pounds of steam per horse-power hour and 7·76 for the binary-vapor machine. Experience only, however, can determine just how far this relation will hold for the life of the plant when all costs, including interest, maintenance and replacement, enter the account. It also remains to be determined by experience whether the figures here assumed may be safely guaranteed in commercial work generally.

CONCLUSIONS.

From what has preceded, it is probably safe to adopt the following:

(1) It has been fully established, by frequent and prolonged experiences with multiple-vapor heat-engines, that they permit the combination of the advantages of the single-fluid multiple-cylinder engine with those of decrease in the cylinder-condensation waste of the single fluid, steam, in the ordinary engine and some gain in mechanical efficiency due increased mean effective pressure at a given temperature-range of engine cycle.

(2) That the binary-vapor engine to-day, as in the days of Rankine and Du Trembley, maintains a lower record than does the single-fluid engine, and this record now stands at, as reported, 8.36 pounds, less than 4 kilograms, per horse-power-hour.

(3) That the question of the practicability of utilization of this form of heat-engine in the industries must be, as

always, ultimately determined by financial results—by its capability of adding to the dividend-paying power of the enterprise into which it may have been incorporated. This means, practically, its freedom from liability to dangerous or annoying or costly accidents and interruptions of its operation.

The thermodynamic aspect of the question is perfectly well determined and understood among engineers, and this practical question can only be decided by time and experience and further experiments in design, construction and operation.

The practical identity of the efficiencies of the triple-expansion and compound engines, when employing moderately superheated steam, the total ratio of expansion and the initial pressures being the same, as in these experiments, has special interest as confirming the deductions which may be made from many other independent experiences —that the internal wastes of the engine being quenched by superheating or other method, the special advantage of the series-engine in this respect disappears. With sufficiently superheated steam, the simple engine would become the equal of the compound or of the triple—so far as this efficiency goes—and yet the gain by the employment of the waste-heat engine would not be in the slightest degree reduced. In fact, should superheating be carried to the extent of increasing the temperature of the steam at exhaust, its usefulness would increase with rise in the final temperature of the exhaust-steam. The value of the ordinary system of compounding is thus decreased while that of the "waste-heat" system is increased, by the adoption of superheating; the series-engine loses value while the series-fluid gains. No known expedient, in fact, can supersede the latter method of extending the thermodynamic action and temperature-range of the steam-engine. Should the commercial aspect of the case prove satisfactory, it may be expected to inevitably take its place as a standard available form of heat-engine. Its theory and thermodynamic characteristics cannot be criticised.

Summarizing the main facts of the investigation, we

may conclude that the best work of the best builders of the steam-engine may be to-day taken as measured by an expenditure of about 11 pounds of dry steam per horse-power hour, corresponding to about 11,000 B.T.U. per hour, which means the heat stored in about three-fourths of a pound of best coal as measured in the boiler. The records of engines employing other fluids than steam have usually shown a better performance than similar engines using steam under similarly favorable conditions, and the "Heat-Waste Engine" has availed itself of the wastes from a steam-engine of the highest type, doing its work better than the average engine of the best builders under most favorable conditions, and has thus reduced the consumption of heat, steam and fuel, from figures approximating those just given to less than 10,000 B.T.U., 8·35 pounds steam, moderately superheated, and to the equivalent, on the above basis, of about two-thirds of a pound of best coal per horse-power per hour as shown on the indicator diagram, and to figures about 10 per cent. larger for delivered power, thus breaking the world's record by a very remarkable margin.

It will be also noted that this gain is produced by following the idea of Cotterill, the writer, and others; of availing ourselves of the opportunity to depress the lower limit of useful temperature-range of the cycle, and of the fact pointed out most clearly by Wood: that differences in efficiency of cycle may be due to differences of physical constitution of working substance in other than the Carnot cycle; as well as of the principle—which has been for years enunciated by the writer and probably recognized by others—that maximum availability of working fluid is obtained when the superior limit of practicability of control of both temperatures and pressures is the same for both, and when, similarly, at the lower limit, the minimum utilizable temperature of the expanding fluid is accompanied by pressure of maximum availability, with, further, a minimum back-pressure.

The ability on the part of the designer, and in perhaps some degree, also, on the part of the operator of the binary

engine, to adjust the pressure, vacuum or plenum, as may prove best, in the vaporizer, to the point of maximum economic effect, may be accepted as one of the valuable elements of this problem, in construction and use of the heat-engine. There must necessarily be a surface-condenser in which to condense the exhaust-steam and to transfer its heat to the secondary element; and this permits the adoption of whatever tension of vapor in that vessel may be found, by experience or more exact experimental investigation—all things considered—to prove best.

The same principle and the same statement apply also to the condenser of the secondary engine, where it may be found desirable to adjust the pressure, similarly, with any given engine and to also adjust the tension of the exhausted vapor to the best conditions for the use of different secondary fluids. Both primary and secondary fluids must be worked in closed cycles, in all such series engines, and the pressure of the external atmosphere disappears as an element of the problem.

In construction, the secondary engine is proportioned to deliver about 40 per cent. of the power of its primary, as a rule, the precise dimensions depending upon the waste-heat to be utilized by it and the relative costs of gains and losses in the primary as well as in the secondary. The adjustment of the two elements of the series-engine is ultimately controlled, as is every engineering problem, by the commercial test; and that final adjustment is sought to be secured which, being attained, any deviation therefrom will produce a greater loss than gain; and any gain secured will be more than counterbalanced by some incidental accession of waste —thermal, dynamic or financial.

It is particularly desirable, with these fluids, to employ forms of valves and gear which shall be easily made and kept tight and shall not cause difficulty in keeping tight all stuffing boxes. Probably the plan employed for many years past on very high-pressure engines, as by the Messrs. Perkins, and by the builders of the Berlin engines here discussed, of making the stuffing boxes exceptionally long, and of rotating the valve-stems rather than moving them

longitudinally will usually be found best. The device of the "lantern-brass" of the old Cornish construction of piston-rod packing is another suggestion from older practice, which may be found valuable for these later constructions, where it can be modified to meet the needs of the new system. In the Berlin engine, puppet-valves were adopted with rockshafts as lifters. The piston-rod stuffing box presented an interesting problem ; but it was finally constructed in such manner that no working fluid reached the outer end at all, the construction being double and the outer portion being made to employ grease as the substance acting as the outer seal. It was also found practicable to entirely prevent the passage of the grease from the stuffing box into the cylinder.

The apparatus of heat-exchange between primary and secondary fluids, and between secondary fluid and the water for condensation and disposal of finally rejected heat, may be designed with from 10 to 15 square feet per horse-power of secondary engine, and 30 to 40 feet, respectively, for vaporizer and condenser. In the Berlin engine, the areas were 753 and 1,720 square feet, and the power indicated ranged from thirty to sixty, the best work being reported when the secondary engine developed about 60 horse-power and about 35 per cent. of the power of the primary machine. They were made of iron, proportioned for pressures of 285 and 115 pounds, respectively, and so arranged that they could be inspected and cleaned without removal of the sulphur dioxide from the system. A suitable arrangement of valves permits cutting off the reservoirs containing the secondary fluids when it is desired to inspect the working cylinder. Safety-valves on both reservoirs—the one between vaporizer and condenser, the other between condenser and the outer air—insure against dangerous pressures.

It is evidently advisable, as is usually entirely practicable, to so design the two elements of the combined machine that the steam-engine may be employed independently should it be found necessary to cease operating the secondary engine, for any reason, or to take it out of the system for general inspection and repair.

In making such a combination, it is seen that the value of the secondary machine increases with the wastefulness of the primary, to which it is to be attached.

Since the contact of sulphur dioxide with air and moisture induces prompt oxidation to sulphuric acid and equally prompt action of the acid upon all common materials of construction, absolute tightness of the vessels containing it and perfect protection against introduction of either air or vapor of water into working cylinder, vaporizer, condenser or pipes, is necessary. Introduction of atmospheric air is usually not to be apprehended during operation, as the pressure of the secondary fluid is commonly at all times in the cycle above that of the external air. Good design and construction may be relied upon to prevent the introduction of water or steam. Professor Josse reports that one of his engines had been examined after a year of constant contact of water and sulphur dioxide with the opposite sides of its condenser surfaces without trouble, and another had at last reports been in use nine months with equally satisfactory result.

The great sensitiveness of the pressures of the volatile fluids to heat-exchanges is a minor disadvantage in their use, as the pressures are liable to fluctuate much more rapidly than is the case with steam; and careful provision must be made against sudden and dangerous increase of pressure with any quick variation of heat-supply as, with a primary fluid, the result of sudden increase in temperature of fire or, with the secondary fluid, a sudden and unusual discharge of heat from the main engine through change of its load.

The accompanying figures show the arrangement of the designs prepared for a set of 1,600 horse-power binary-engines on this general plan. It is not important, however, that this particular arrangement should be adopted. The binary engine offers quite as much freedom in location of parts and their relative distribution as the condensing steam-engine of similar power, or as the multiple-cylinder engine of standard forms. The two elements of the binary machine may be set on a frame or they may be placed inde-

pendently, except as to connections, as is sometimes the case with a compound steam-engine, the high-pressure element of which may be at one point and may drive one section of machinery, while the low-pressure element may be an independent engine, as to construction, placed apart and em-

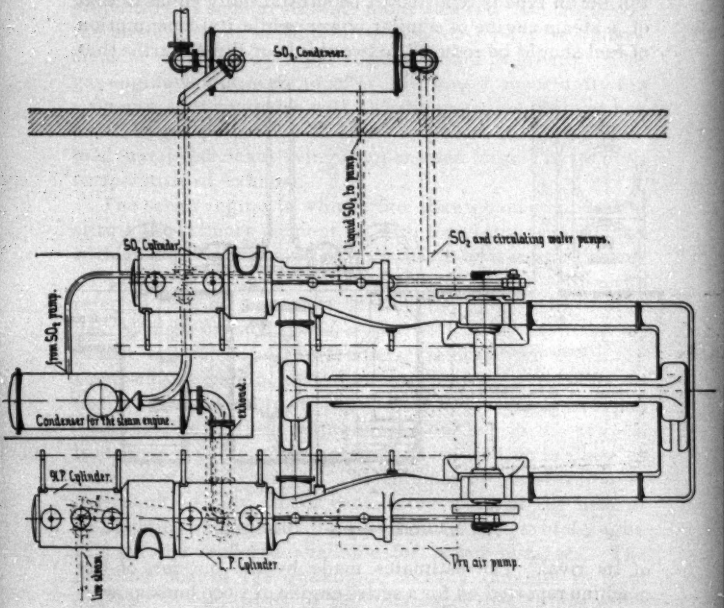


FIG. 13.—Binary engine. 1,600 I.H.P.—Plan.

ployed in driving another section of the machinery of the establishment.*

The Financial Problem is here, as always, the finally determining element of the case. If the ultimate and complete

* This disposition was actually made by Mr. Charles E. Emery, where circumstances were especially favorable.

reckoning exhibits a net gain of sufficient magnitude to justify a proposed installation, the new device will certainly be adopted; if not, whatever the apparent gain in thermodynamic efficiency, it will never be successful.

The costs of construction of the binary-vapor engine of the Berlin type is reported to be substantially equal to that of a steam-engine of similar power, while its consumption of fuel should be reduced to two-thirds or three-fourths that

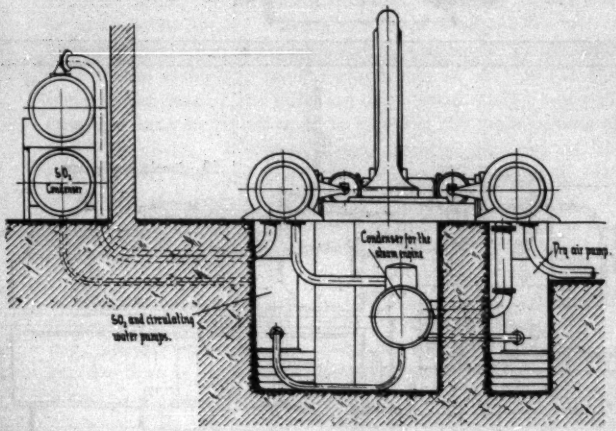


FIG. 14.—Binary engine. 1,600 I.H.P.

of its rival. The estimates made by the builders of the machine reported on for a series-engine of 1,600 horse-power, indicate substantial quality when comparing a triple-expansion steam-engine with a compound steam-engine supplemented by a "waste-heat engine;" reckoning the former as inclusive of 1,600 horse-power of boilers, the latter requiring 1,200 horse-power. The actual difference in the estimates is 3 per cent. on total cost in favor of the steam-engine. A similar comparison of a triple-expansion steam-engine with an equivalent 175 horse-power gas-engine indicates a difference in favor of the latter amounting to about 4 per cent.

The larger machines are estimated at about 125 marks ($31) per horse-power; the smaller at something less than 300 marks ($75) per horse-power. For the larger plant, above described, the cost of fuel in operation is estimated at about 12,600 marks ($3,150) per annum, less for the binary machine; for the smaller plant, the gain should be in somewhat larger proportion, as smaller sizes are more wasteful than large, and the waste of heat, capable of utilization by the secondary element of the binary-vapor engine, should be greater. The gas-engine would seem to offer still larger opportunity for economy, as it competes with the steam-engine, and yet has a still larger proportion of waste to power, its higher thermodynamic efficiency being compensated largely by its high temperature of exhaust.

The series-engine, in which other than steam-engines constitute the primary element, as with a gas-engine combined with an ether-engine, or where the waste-heat engine derives its supply of energy from other sources of waste than the rejected heat of a primary heat-engine, as in utilizing the heat of blast-furnace gases, or that of heating furnaces, or, in fact, any source of low-temperature heat from which the steam-engine cannot derive energy profitably, remains an untried but, probably, in many cases, a promising scheme. The outcome of these experiments has led to the suggestions that even hot-mine waters may be used, as in Chile, as a source of such energy. The chimney of the steamboiler carries off, usually, 20 per cent., often more, of the heat of combustion and, by utilizing a mechanical system of draught, this may be rendered available for power purposes. The rejected heat of the gas-engine usually amounts to from one-half to two-thirds of the total, and this, as has often been proposed, may be employed in any form of successful heat-engine employed as a secondary element, increasing the delivered power in some such proportion as has actually been attained, with the steam-engine as a primary.

It remains an interesting question whether the costs of construction may not be considerably reduced by the adoption of much lower areas of surface-condensers than were in this case employed. The fact is familiar to all who have to

do with marine engineering, that it is usually amply sufficient, with the marine steam-engine, to provide about 3, and sometimes as low as 1 or 2 square feet of cooling surface per I.H.P., while the work to be done and the weight of steam to be handled per horse-power is commonly considerably greater than with the combined engine as here reported. It is true, that in the latter the heat must be twice thus transferred, instead of, as in the steam-engine, but once; but it is here reported that 5 to 7·5 feet should be provided in the vaporizer, and about four times these large figures for the final condensation. It would seem probable that it may be ultimately found that proportions far nearer those which long experience has given the condenser of the steam-engine may be safely and economically adopted for the combined engine.

Should the figures here deduced be confirmed by longer experience, it would seem to be good evidence of a much greater reluctance to heat-transfer on the part of the secondary fluid than is exhibited by steam. On the other hand, this deduction has already been drawn from other experiences in the use of the volatile fluids, especially with ammonia and with carbon-disulphide. This would account for the large demand for cooling water.

The ultimate test of efficiency also remains to be applied: the absolute and relative costs of power-production under these various conditions and with the various combinations of primary and secondary engine, measured in thermal units per unit of power. This happens to be a case in which this final reduction to the ultimate measure is essential to exact conclusions.

If it be assumed, as believed by the promoters of the "waste-heat engine," that, "constructively, the engine is now so far perfected that nothing stands in the way of its employment," and that "the prejudices, existing especially against the employment of sulphur dioxide, are entirely without foundation, *when the apparatus is in skilful hands*" (the italics are introduced by the writer) new installations may be profitably constructed on this plan, and the gain by introduction of the supplementary engine in existing and

even fairly economical plants may be expected to be still larger—always provided later experience shows depreciation, accident and interruption of operation by all the various causes incidental to the use of prime movers to be no greater than with well-constructed stem-plants.

INSTALLATION COSTS—COMBINED STEAM-WASTE HEAT PLANT OF 1,600 HORSE-POWER.

The cost of the engine proper, consisting of compound steam-engine of 1,200 I.H.P. and a cold-vapor cylinder of 400 I.H.P., together 1,600 I.H.P., for 72 revolutions per minute and including a sulphur-dioxide pump, vacuum pump and cooling water pump, for the price of	$31,250
One vaporizer for the cold-vapor engine	2,500
Two condensers	6,000
Valves	1,000
Extra for pipe-system	1,750
First supply of sulphur dioxide	.500
Two steamboilers with superheaters for 1,200 I.H.P.	8,000
Total	$51,000
On the other hand, the costs of a triple-expansion installation for 1,600 I.H.P. and 72 revolutions per minute, consisting of high-pressure, intermediate and two low-pressure cylinders, including two jet condensers and two air-pumps, would cost, when constructed by the same steam-engine builder	$37,500
Two boilers and superheaters for 1,600 I.H.P.	14,000
Total	$51,500

Book Notices.

Geschichte der Moränenkunde von Dr. August Böhm Edlen von Böhmersheim, Privatdocenten an der K. K. Technischen Hochschule in Wien. Mit 4 Tafeln und 2 Textfiguren. *Abhandlungen der K. K. Geographischen Gesellschaft in Wien*, III. Band 1901, No. 4. Wien 1901, R. Lechner (Wilh. Müller) K. u. K. Hof u. Universitäts-Buchhandlung.

This important work covers 334 small quarto pages and is an exhaustive presentation of everything known to-day about moraines. It is divided into four principal parts—the history of moraines; the glacier conference of August, 1899; the classification of moraines; and an elaborate bibliography.

Dr. v. Böhm traces the subject of glaciers back to Seb. Münster in 1544, but he finds the first suggestion of moraines, under another name, in a curious poem of H. R. Räbmann in 1606, "Talk Between Two Mountains." The term moraine occurs first in a paper by Besson (1777–1780), who heard the word in Savoy, but who wrote it *marême*, in which spelling he was corrected

by De Saussure (1796). Dr. v. Böhm treats at length of all the well-known writers who have touched on moraines, such as DeLuc, Rendu, Charpentier, Agassiz, Escher v. d. Linth, Forbes, Dollfus-Ausset, Tyndall, etc., but it would be impossible to give briefly a tithe even of the names of the numerous writers and observers whose observations and theories he carefully notices.

Besides a lengthy criticism of the glacier conference and of the various theories now held about moraines, Dr. v. Böhm gives his own views of moraines and offers a system of classification to help clear up the terminology of the subject. His book is certainly a valuable and original contribution to the knowledge of glaciers and it deserves the attention of all glacial geologists.

E. S. BALCH.

American Rifleman's Encyclopedia, being a collection of words and terms used by riflemen of the United States, with definitions and explanations for rifle-shooting. Compiled by A. C. Gould, Editor of *Shooting and Fishing*. 12mo, pp. 137, paper covers. The Peters Cartridge Company, O., N. D.

The principal contents of this booklet is clearly expressed in the sub-title. In addition to the glossary, the volume contains much miscellaneous information of value to those interested in rifle-shooting. W.

Übungsbeispiele für die Electrolytische Darstellung chemischer Präparate. Zum Gebrauch in Laboratorium für Chemiker u. Elektrochemiker. Von Dr. Karl Elbs, o. Prof. u. Direktor der Laboratoriums für phys. u. org. Chemie on der Universitäl Giessen. Mit 8 Abbildungen in Text. 8vo, pp. 108. Halle a. S. Druck u. Verlag. von Wilhelm Knapp. 1902. (Price, M. 4.)

The rapidly growing literature devoted to electrochemistry is evidence of the rapid growth of the industry. Until recently the leading universities and technical schools here and abroad devoted either scant attention or none at all in their laboratories to electrochemical practice. Now, all this is changed.

The present work is intended as a laboratory guide for students in electrochemical practice, and the student is given a series of examples illustrating the several types of electrolytic decompositions and recompositions with inorganic and organic compounds. It is the first work that has come to our notice treating of the subject of electrolytic synthesis as a guide to the student, and we have no doubt that instructors in this branch of applied science have often severely felt the want of something of the kind. W.

A Manual of Photo-engraving, containing practical instructions for producing photo-engraved plates in relief-line and half-tones. By H. Jenkins. With supplementary chapters on the theory and practice of half-tone color work, by Frederic E. Ives and Stephen H. Horgan. Second edition. Chicago: The Miland-Procter Company, 1902. (Price, $2.)

The present edition of this work has been thoroughly revised and brought up to date. The author gives full and explicit details of the various processes involved in the production of the several classes of photo-engravings, with a series of very instructive picture-illustrations.

The addition of a chapter by F. E. Ives on three-color-process theory and half-tone-process theory, and a thorough exposition of the practical workings of the three-color process, by Mr. S. H. Horgan, add to the value of the book. W.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, November 19, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 19, 1902.

President JOHN BIRKINBINE in the chair.

Present, 72 members and visitors.

Mr. Louis E. Levy offered the following resolution, which was duly adopted:

Resolved, That the Board of Managers be requested to appoint one or several delegates from its members at present residing or temporarily sojourning in Paris, to represent the Institute at a meeting of the Association of Inventors in France, and present a testimonial to M. Millerand, Ex-minister of Public Works, Posts and Telegraphs, for his services in promoting the amendment of the Patent Laws of France in the interest of inventors.

Mr. John S. Seymour, of New York, late U. S. Commissioner of Patents, presented a communication describing the acetone-acetylene system devised by Messrs. Clande and Hess, for the safe storage and transportation of acetylene, and exhibited the apparatus in operation.

The communication was freely discussed and, at the close of the discussion, the meeting passed a vote of thanks to the speaker of the evening.

Adjourned.

WM. H. WAHL, *Secretary*.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Monday, Nov. 5, 1902.*)

MR. THOS. P. CONARD in the chair.

The following reports were adopted:

(No. 2238.) *Electrical Distribution and Interior Wiring.*—Luther Stieringer, New York.

ABSTRACT.—The report considers in general terms a series of contributions to the art of electric illumination made by applicant, many of which are subjects of patents. These improvements cover principally systems of electrical distribution and interior wiring. Applicant's work was done at a time when no precedent had been established and forms the basis of the present system of fixture wiring and interior distribution, including what is known as the panel system of wiring.

The report alludes also to applicant's original work in decorative lighting, the installation of nearly all the large expositions held in this country having been carried out by him personally, or laid out on the lines suggested by his work.

The report concludes by recommending the award of the John Scott Legacy Premium and Medal to applicant "for his invention of insulating joints essential to combination fixtures for gas and electric light, for improvements in interior lighting and for the excellent information and descriptions

which he has given in connection with decorative lighting." [*Sub-Committee.*—W. C. L. Eglin, Chairman; Thomas Spencer, E. A. Scott.]

(No. 2214.) *National Machine Tool Company's System of Gearing.*—National Machine Tool Company, Cincinnati, O.

ABSTRACT.—This device is the invention of William L. Schellenbach, and consists of a method for rapidly and conveniently changing the gearing of screw-cutting lathes for cutting threads of various pitches. (Detailed description of the device is impracticable without the aid of illustrations).

The report concludes: "The device is very ingenious and materially facilitates the changing of ratio in screw-cutting, as a re-setting will occupy only a few minutes of time. Of course, exceptional cases will arise when an odd or unusual pitch is to be cut which does not happen to be within the list of possible combinations of the device. Recourse may then be had to a change of the gear-wheel on the screw and a re-clamping of the device on the lathe.

"The device is only adapted for lathes, on which the leadscrew is also used as a splined rod for the feed. On lathes having a separate splined rod the device is in the way of the feed-belt and cannot be permanently attached to the lathe. But in cases where it is applicable, your Committee considers it to be decidedly advantageous." The John Scott Legacy Premium and Medal is recommended to applicant. [*Sub-Committee.*—Hugo Bilgram, Chairman; Henry F. Colwin, Jacob Y. McConnell, Geo. S. Cullen.]

(No. 2207.) *Sectional Models for Stereometric Representation.*—W. C. F. Morsell, Philadelphia.

ABSTRACT.—After a careful study of the models and accompanying descriptive matter, the Committee expresses the opinion that they are well adapted to the illustration of sequence of form in the study of mensuration and solid geometry; that they demonstrate clearly the relation of the basal cubes to the solid forms derived by the use of cutting planes; and that these models can be made of especial value in manual training and other schools in which the study of the form can be supplemented by the construction of similar models by the individual pupil.

In consideration of this opinion, the report makes the award of the Edward Longstreth Medal of Merit to applicant. [*Sub-Committee.*—Geo. A. Hoadley, Chairman; Jos. W. Richards, L. F. Rondinella, Amos P. Brown.]

The following reports passed first reading, viz:

(No. 2257.) *Blue Printing.*—Sam'l Brent Whinery, Pittsburg, Pa.

(No. 2206.) *Turret Lathe.*—J. W. von Pillter, Leipzic-Gohlis, Germany.

(No. 2222.) *Theory of Musical Harmony.*—Victor Goldschmidt, Heidelberg, Germany.

(No. 2232.) *Process of Making Open-Hearth Steel.*—Benjamin Talbot, Philadelphia.

(No. 2235) *Hydraulic Ram,*—Chas. C. Wentworth, Roanoke, Va.

(No. 2242.) *Electrolytic Process for Alkali and Bleach.*—Charles E. Acker, Niagara Falls, N. Y.

(No. 2251.) *Bridging Bell System for Telephones.*—John J. Carty, New York.

No. 2256.) *Acetylene Generator.*—G. P. Rush, Philadelphia.

(This was made advisory and adopted.)